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The Electric Strain Gage and Its Use in Textile Measurements

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The general principles of the bonded metalectric strain gage are given, and some specific applications to certain general problems are discussed. The variables in the measuring system are considered, the importance of each is shown, and the choice of the proper units for solving a given type of problem is indicated. Formulas are given as references for any design work the reader might wish to undertake, and derivations not already in the literature are presented. Some data concerning various instruments are reported as an indication of the results which can be achieved and to point out certain important differences which result from this type of measurement, as opposed to data obtained on conventional equipment.

THE need for a clearer understanding of load-deformation relationships in textile materials and their dependence on conditions such as rate of loading, gage length, temperature, relative humidity, etc., has led to an investigation of these relationships in the Samuel Slater Memorial Research Laboratory at the Massachusetts Institute of Technology. These investigations have in turn led to new techniques of measurement employing the bonded metalectric strain gage.

This type of strain gage, although a comparatively recent development in the engineering field, has proved to be a powerful tool for investigating the mechanics of materials. It has been extensively used in work on metals, yielding much interesting information, and has more recently been applied to textiles.

The gage makes use of a familiar electrical principle—namely, that metal wires change their resistance when strained. For ease in interpreting in terms of strain it is desirable that this resistance-strain relationship be linear, and by carefully choosing the proper type of wire linearity can be achieved for strains below the yield-point strain of the wire. Working beyond the yield point leads to undesirable permanent deformatives, making this a necessary limitation. Similarly, by use of appropriate electrical circuits, this resistance change can be converted to a voltage change which can be

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In subsequent articles specific applications of these techniques to the testing of textiles, together with quantitative experimental data, will be presented.

measured on various types of recording instruments. Thus the gage allows electrical measurement of strain. And where stress is proportional to strain, this can be interpreted in terms of stress.

Normally, in testing metals, the deformation in the gage is caused by the deformation of some surface of interest, to which the gage is bonded. However, because textile materials have high extensions and surfaces unsuitable for bonding, this method of directly cementing the gage to the surface in question cannot be used. The difficulty may be overcome by cementing the gage to a suitably designed weighbar which is placed in series with the textile specimen.

Figure 1 shows this arrangement schematically. Here the load applied by the textile specimen, P, produces a strain in the surface to which the gage is cemented, which is picked up by the strain gage and can be recorded on an appropriate voltage-measuring instrument.

Thus by use of proper weighbars and circuits the strain gage can be used to measure tensions and loads acting upon, and the weights of, textile specimens under varying conditions of interest.

Advantages of the Strain Gage

The gage as a measuring instrument has the advantage that wherever it is used it can be made to record continuously the changes in whatever phenomenon is being investigated. It can be incorporated into a measuring circuit of high sensitivity by proper choice of the mechanical and electrical components of the system. Since the measurements are primarily electrical, many results can be achieved simply which would be difficult and complicated to achieve by mechanical means. Furthermore, it has the decided advantage that there is virtually no inertia in such a measuring system, so that any data obtained are true sample characteristics uncolored by the characteristics of the instrument used for measuring. By the same token, the response of the instrument is good, so that quick changes in the measured phenomenon can be faithfully recorded, a result not achieved with most conventional present-day testing machines.

The gage is simple and economical to use because it does away with the precise machining necessary in mechanical measuring systems, such as dynamometers. It is comparatively rugged, in that it does not require the precise bearings or springs used in conventional dynamometers. Easy calibration of the measuring circuit is permitted; therefore results are more certain, and any small changes in machine characteristics with time can be picked up by frequent check calibrations.

The gage can be used over a large range of capacities on the same equipment, with only small changes in the constants of the measuring circuit. By making proper adjustments, a reasonable sensitivity can be maintained. Conversely, it will be recalled that in the case of standard strength-testing machines, for example, different machines are used to test different capacities, and that even on the same machine, when tests can be made at more than one capacity the rearrangement of the machine is somewhat bothersome.

Since external conditions such as temperature and humidity do not materially affect the performance of the gage, this type of measurement can be used under varying external conditions. The strain gage has been found to work well in the temperature range from below 0 to 450°F, over long periods of time, and can be used at relative humidities from 0 to 100 percent.

Furthermore, because the circuit allows simple calculation of its response frequency, it is possible from such a calculation to predict the accuracy within certain limits. To define the response of a mechanical dynamometer, however, involves calculations with uncertain factors such as friction forces, etc.

The Strain Gage System—Its Component Parts and Principles

As has been previously indicated, there are various types of strain gages, weighbars, and electrical circuits which can be used for this type of measurement. In order later to show the considerations involved in choosing the component parts of the system for the solution of some types of problems, a discussion of these parts and their limitations will be undertaken in some detail.

The first consideration is the wire to be used in the

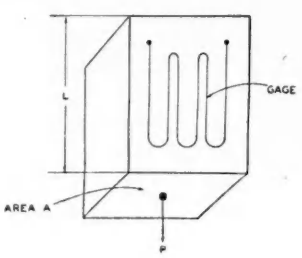


FIG. 1. *Schematic diagram which illustrates the principle of an electric strain gage.*

gage. This wire must satisfy certain conditions. It must deform and recover elastically, and must have a linear resistance-strain curve up to certain limits—that is, the expression

$$\frac{\Delta R}{R} = F\frac{\Delta L}{L} \qquad (1)$$

must be satisfied,

where $\Delta L/L$ is the strain in a length L,
R is the resistance in a wire of length L,
ΔR is the change in resistance for strain $\Delta L/L$,
and F is a constant (the gage factor).

Furthermore, because the passage of electrical current through a wire produces heating effects, the wire must also have a resistance which is stable with temperature changes [1]. After much experimenting, two types of wire were chosen by the inventors of the gage as meeting the above specifications most satisfactorily. They are constantan and iso-elastic wire with temperature coefficients of resistance of 10^{-6} Ω/Ω/°F and 10^{-4} Ω/Ω/°F respectively.

If wire of one of these types is wound in a group of parallel segments, as shown in Figure 2, and the wound wire is then enclosed in an insulating medium, the result is an electric wire strain gage. Leads are provided from points A and B. Now, in the length L, we have an effective length of wire nL, where n is the number of parallel segments. And for a deformation of the surface ΔL, we find a deformation in the wire $n\Delta L$ so that the strain in the wire is still $\Delta L/L$. Furthermore, the relationship $(\Delta R/R) = F(\Delta L/L)$ still holds, and, R being larger than for a single wire of length L, ΔR becomes larger, so that sensitivity is increased without substantial increase in the length of the working surface. It might be expected that the turns produced in winding the gage to shape can produce errors in the linearity of the resistance-strain relationship, but because the wires are highly insensitive to transverse strain this does not affect the result appreciably in an axial stress field. Actually, the gage factor, F, and therefore the sensitivity of the measurement, is slightly changed. In the case of two-dimensional stress fields, corrections for this effect have been worked out [2].

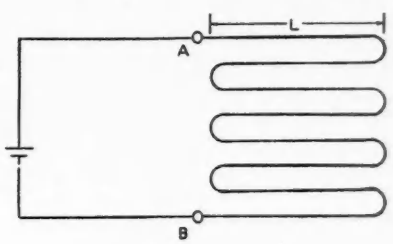


FIG. 2. *Parallel arrangement of wire in an electric strain gage.*

The gages commercially available are of two basic types, type A and type C. Type A is made with constantan wire and type C with iso-elastic wire. The insulation is also of two types, paper and Bakelite. The Bakelite insulated gages using both wires are known as types AB and CB. The type A gage, while being better temperature-compensated, has a lower gage factor (about 2.0) than the type C gage (about 3.5), so that more sensitivity can be had by the use of type C gages.

About twenty-five variants of each of these types are available commercially. Type A gages vary from 1/8 inch to 6 inches in gage length and from 120 Ω to 500 Ω in resistance, and type C gages run from 1/8 inch to 1 inch, and 350 Ω to 2,000 Ω.

The gages are also available in rosette combinations of the equiangular and 45° types, for the determination of principal strains in various stress fields.

In bonding the gages to the weighbar, two types of cement are used: Duco for the paper-covered gages and Bakelite cement for the Bakelite insulated gages.

Tests have been run on these cements to determine the amount of flow and slipping which occur during straining, and errors due to these effects have been found to be negligible.

The Bakelite bonded gages are often used for work in high-temperature regions. They will stand steady temperatures of 400°F and have been known to work for short periods at 600°F.

In the use of both types of gages it is important to waterproof the gages thoroughly with a covering of some moisture-repellent substance such as wax. Because the cements and insulation are hygroscopic, improper waterproofing allows both elements to change their moisture content, thus in effect changing the resistances in parallel with the gages, and leading to errors in measurement.

Weighbars

The weighbar shown in Figure 1 is the simplest, being a rectangular parallelopiped made of a suitable metal. This type is useful for the measurement of high loads and has been used successfully in weighing aircraft [3].

In Figure 1 it will be seen that a load, P, acting on the textile specimen results in a stress, P/A, in the metal weighbar, producing a strain $(\Delta L/L)$

$= (P/JA)$, where J is the modulus of elasticity of the metal.

Because $\Delta L/L$ should be high for the comparatively small load, P, it is necessary that the area A be small. The surface to which the gage is attached should be large, however, to allow for the attachment of a relatively large amount of wire, thereby giving greater sensitivity. It is also desirable, because of possible bending in the weighbar, to have the strain-sensitive wires attached all around the weighbar, thus averaging out bending effects in any direction. With these restrictions in mind, it is sometimes desirable to use a tubular-type weighbar (Figure 3).

The hollow tube is usually made of brass, which has a sufficient modulus of elasticity and tensile strength. The wire is wound parallel to the axis of the tube and all the way around it.

Figure 4 shows another type of weighbar which is extensively used—the cantilever beam type. The diagram represents a beam of height h and width b. The load, P, is applied at point B and the strain gage is cemented at point A (at a distance L from B). From the elementary theory of beams the stress produced at point A, f_c, is:

$$f_c = \frac{Mc}{I} \tag{2}$$

where M (the moment about point A) $= PL$; c (distance from the neutral axis to point A) $= h/2$; I (the moment of inertia of the section at point A) $= \frac{bh^3}{12}$.

Therefore,

$$f_c = \frac{6PL}{bh^2} \tag{3}$$

also

$$\frac{\Delta L}{L} = \frac{f_c}{J} = \frac{6PL}{Jbh^2}$$

and

$$\frac{\Delta R}{R} = F\frac{\Delta L}{L} = \frac{6FPL}{Jbh^2} \tag{4}$$

Examination of equation (4) shows that the variables influencing the sensitivity of the weighing system are:

F, the gage factor.

L, the distance along the beam from the point of application of load to the strain gage. The greater this length, the more sensitive the weighbar.

J, the modulus of elasticity of the metal. The lower the modulus, the higher the sensitivity.

b and h, the cross-sectional dimensions. The thinner and narrower the beam, the more sensitive the system.

Actually, the gage is not bonded to a point but to a finite length, so that the recorded strain, although linear with load, is an average of strains along the gage. If the strain on the entire gage could be raised to that at the point farthest removed from the load, the system would become more efficient.

This increase can be affected by suitably changing the dimensions of the cantilever, and sloping the sides linearly, as in Figure 5. Here the stress f_c is independent of the distance from the load and for this case

$$\frac{\Delta R}{R} = \frac{6FP}{Jkh^2} \tag{5}$$

where k is the slope of the sides of the beam. Such beams are valuable for certain types of measurement.

Electrical Circuits

There are four types of circuits which are in general use and into which the strain gage may be incorporated regardless of the weighbar on which it is mounted. These are: (1) the single gage and ballast resistance circuit, (2) the series circuit, (3) the D.C. bridge circuit, and (4) the A.C. bridge circuit.

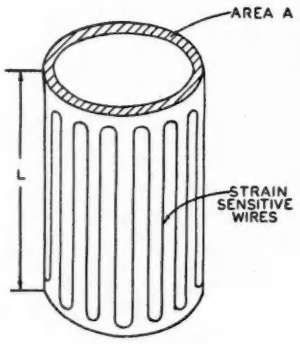


FIG. 3. *Tubular-type weighbar.*

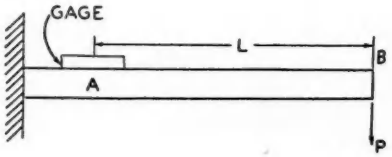


FIG. 4. *Cantilever-type weighbar.*

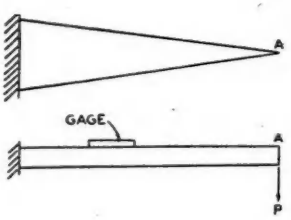


FIG. 5. *Cantilever weighbar with sloping sides.*

1. The Single Gage Circuit. Basically the circuit is that of Figure 6. A source of E.M.F. delivering E volts is placed across a fixed ballast resistance, R_B, in series with the gage, of resistance R_G. The voltage drop (V) across the gage is measured. If I stands for the current in the circuit, then

$$I = \frac{E}{R_B + R_G}$$

and the voltage drop V is

$$V = IR_G = \frac{ER_G}{R_B + R_G}$$

Differentiating with respect to R_G yields

$$dV = \frac{E}{(R_B + R_G)^2} R_B dR_G$$

and, substituting I for $E/R_B + R_G$,

$$dV = \frac{R_B}{R_B + R_G} I dR_G \qquad (6)$$

Therefore the change in voltage across the gage is linear with resistance changes, except for second-order effects introduced because $R_G = R_{G_0} + dR_G$, where R_{G_0} is the gage resistance at zero strain.

By substituting this expression for R_G, in equation (6), it can be shown that the deviation from linearity is negligible for small strains.

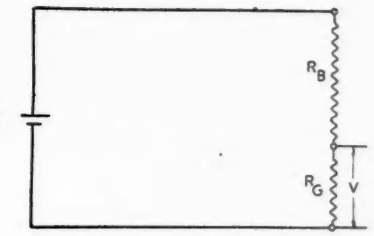


FIG. 6. *Basic single-gage electrical circuit with ballast resistance.*

FIG. 7. *Series circuit.*

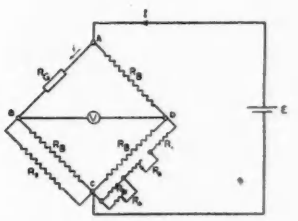


FIG. 8. *Basic D. C. bridge circuit.*

2. The Series Circuit. Adding more strain gages to this circuit results in a series circuit as shown in Figure 7.

Assuming that there are k gages in series and specifying the resistance of the nth gage as R_{G_n}, then the current in the circuit, I, is

$$I = \frac{E}{R_B + \sum_{n=0}^{k} R_{G_n}}$$

and the voltage drop across the nth gage is

$$V_n = IR_{G_n} = \frac{E}{R_B + \sum_{n=0}^{k} R_{G_n}} R_{G_n}$$

Differentiating with respect to R_{G_n} yields:

$$dV_n = \frac{R_B + \sum_{n=0}^{k} R_{G_n} - R_{G_n}}{[R_B + \sum_{n=0}^{k} R_{G_n}]^2} E dR_G$$

and, summing over n,

$$dV = E \sum_{n=0}^{k} Q dR_{G_n} \qquad (7)$$

where Q is some factor, depending on R_B and R_G, known as the efficiency factor.

Again the change in voltage is linear with the resistance change, and the total voltage change is the sum of the voltage changes produced by each gage. A series circuit is thus used when greater sensitivity is desired. It may also be used to rectify bending errors in the weighbar by bonding gages to opposite sides of the weighbar, and placing them in this type of circuit. The voltage change recorded is then a function of the average of the strains imposed on the gages. If the bar is bent during loading, one gage will read higher than the correct strain and one lower, and the averaging achieved by the circuit eliminates this bending effect.

3. The D.C. Bridge Circuit. This type of circuit makes use of the unbalance of a Wheatstone bridge to measure resistance changes. The four legs may be made up of one, two, three, or four active gage resistances with the rest ballast resistors of approximately the same resistance. The bridge in Figure 8 shows one active gage resistance, R_G.

Because gages vary slightly in resistance as manu-

factured, and more variation is produced by slight deviations in techniques of bonding, it becomes necessary to provide means of initially balancing the bridge. The resistors R_1, R_2, R_3, R_4, and R_5 in Figure 8 are included for this purpose. R_5 is fixed (5,000–10,000 Ω). R_1 is fixed at about one-half R_5, so that the right lower leg of the bridge cannot be

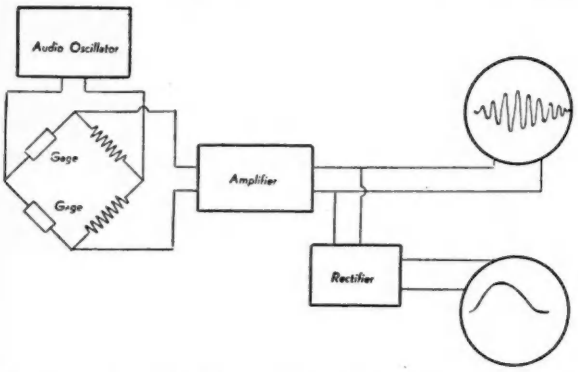


FIG. 9. *Schematic diagram of A. C. bridge for use with electric strain gage.**

shorted out, thus protecting the voltage recorder. R_2 is a large variable in series with R_1, to provide a coarse balancing adjustment, and for fine balance R_4 (about 10Ω) is placed in series with R_1 and R_2, with R_3 (variable 1,000 Ω) in parallel with R_4.

A constant source of E.M.F. of E volts is maintained across AC by means of batteries or a power pack. Because R_1 and R_5 are large compared with R_G, and R_G is approximately equal to R_B, the current I in one leg of the bridge is approximately ($I = E/2R_G$). And the voltage drop (V) across BD is zero for the balanced bridge. Consider now what happens when the gages are strained, $\Delta L/L$ leading to a resistance change in the gage ΔR_G. Where ΔR_G is small, R_G may be regarded as approximately constant, and therefore I is approximately constant, so that ΔV, the change in measured voltage across BD, is

$$\Delta V \approx I\Delta R_G$$
$$\approx \frac{E}{2R_G}\Delta R_G \qquad (8)$$

Here, again, the measured voltage change is linear (except for negligible errors) with change in resistance.

4. The A.C. Bridge. The A.C. bridge is schematically represented in Figure 9. The input voltage is fed from an oscillator at a given frequency, ω, depending on the specific application. The circuit is free of inductance but there is some capacitance unbalance. Thus it is necessary to balance capacitance as well as resistance initially, but because resistance changes are small, the capacitance remains in balance during the test. Therefore the change in impedance with strain, ΔZ, is equal to the change in resistance ($\Delta Z = \Delta R_G$).

In the case shown, two legs are active so that the total impedance change through those legs is

$$\Delta Z = 2\Delta R_G$$

Also, as in the case of the D.C. bridge,

$$\Delta V = I\Delta Z = 2I\Delta R_G$$

In this case, however,

$$I = I_a \sin \omega t$$

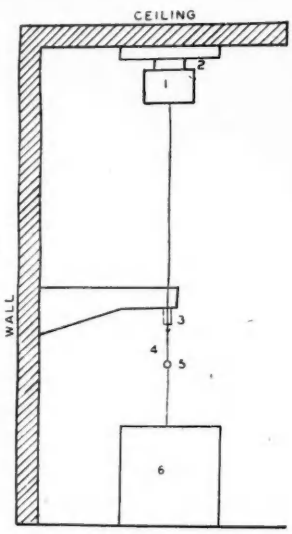
so that

$$\Delta V = 2I_a\Delta R_G \sin \omega t \qquad (9)$$

Thus the gage has the effect of modulating the amplitude of the input voltage proportionally to the change in resistance. Usually this type of circuit requires amplification, and after coming through the amplifier the wave form is that schematically shown in the upper indicating circle in Figure 9. The rectified curve, shown in the lower circle, is a plot of the amplitude of the modulated wave with time, so that ΔV as measured after rectification is:

$$\Delta V = 2I_a\Delta R_G \qquad (10)$$

Therefore, the voltage change is linear with the change in resistance.



The capacitance- and resistance-balancing circuits in parallel with the legs of the bridge are omitted in Figure 9 to avoid confusion. They

FIG. 10. *Principle of the falling weight employed in the Slater Impact Tester.*

* Figures 9, 15, and 16 are published through the courtesy of G. S. Burr, formerly of the Mechanical Engineering Department of M. I. T.

are essentially similar to those shown for the D.C. bridge.

Criteria for Gage Selection and Application

In order to use the foregoing method of stress measurement to the best advantage it has already been pointed out that there are several factors which must be considered in the selection of the proper component parts of the weighing and recording systems. It will be our purpose in the following paragraphs to present three applications of the strain gage and to discuss these factors, leading finally to a selection of each important part. The three examples cover, to a large extent, the typical problems that one is likely to meet in dealing with this method of stress measurement. The first is an impact tensile test for yarn and fabrics; the second is a slow-speed compression test; and the third is a method for the continuous recording of the rate of moisture regain for samples of either loose fiber or fabric.

1. Impact Test (Slater Impact Tester)

Figure 10 shows schematically the apparatus in use. A heavy weight (1) held by an electro-magnet (2) is dropped to apply an impact load on the sample (4). The sample is inserted into specially designed jaws which are in series with the weighbar (3). The weight is so constructed that when released from the magnet it descends past the sample and jaws, picks up a bar (5) attached to the lower jaw, and carries it to the base (6). The size of the weight selected is such that the energy required to rupture the sample is small enough as compared to the energy of the falling weight to make the change in the rate of strain during test negligible. The strain gage is incorporated into a suitable electrical circuit and a high-speed camera and oscilloscope are employed to record the resultant load-deformation curve.

A typical example of the application of the principle of the impact test is a problem which had to do with the measurement of the low-deformation characteristics of several aeronautical fabrics under conditions similar to those met in actual service use. The necessary condition of load specified was to rupture the specimen in approximately 1/100 second at a constant rate of strain. In the discussion in regard to the selection of parts for the system, which occurs later in this article, this particular problem will be kept in mind.

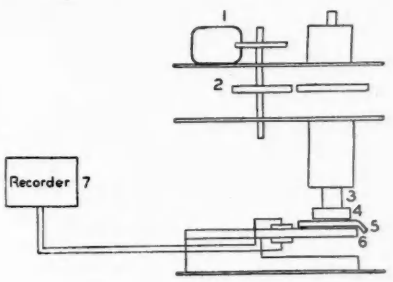


FIG. 11. *Operational principle of the Slater Compression Tester.*

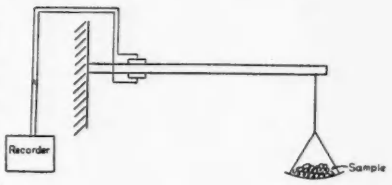


FIG. 12. *Use of the strain gage principle in the measurement of moisture regain in a textile sample.*

2. Slow-Speed Stress Measurement (Slater Compression Tester)

Figure 11 illustrates schematically the operational principle of the compression tester, used here to illustrate a typical case of slow-speed stress measurement.

A synchronous motor (1) drives through a series of gears (2), a splined shaft (3), either up or down, depending upon the direction of rotation of the motor. To the lower end of the shaft is attached a circular foot (4) used to compress the sample (5). The sample rests on the top face of a cantilever (6) to which are bonded a number of electric strain gages. The gages, wired into a suitable electrical circuit, deliver a continuous varying voltage signal corresponding to the changes in compressive load imposed on the sample by the moving shaft. The speed of travel of the shaft being known, the diagrams, plotted against time, using a photoelectric recording potentiometer (7), can be interpreted as the load-deformation characteristics of the sample under test.

3. Measurement of Weight (Moisture Regain Tester)

In both the above examples the deflection, as will be pointed out later, has been limited to a given value, resulting in a corresponding limitation of sensitivity.

In the third example it is not necessary to keep the upper jaw relatively fixed. When, as in the previously described cases, it is desired to obtain a stress-strain relationship, it is clear that any move-

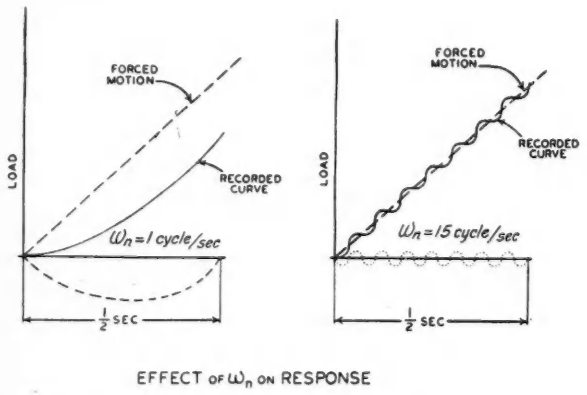
ment of the gage system, beyond certain limits, would lead to a variable rate of strain. Interest in the following test is confined to the weight on the cantilever, thus allowing a sizable deflection of the beam and, as a result, making possible a high sensitivity system without the use of complicated preamplifiers.

As shown in Figure 12, a sample of loose fiber or any textile material which has been subjected to a drying treatment is hung from a cantilever of the proper dimensions, to which has been bonded a set of strain gages. As the sample changes in weight because of regain of moisture, the stress in the beam increases and, following through the changes which take place in the gage, as previously discussed, it is possible to record continuously the rate of moisture regain of the sample in question.

Having briefly outlined these three examples of stress measurement, let us take up each in detail and attempt to justify the selection of the various parts of the weighing and recording systems.

Case 1—The Impact Test

A. Weighing System. The first consideration is the selection of the type of wire for the strain gage itself. This choice is usually influenced by the duration of the test, since it is desirable that the resistance of the gage remain constant during the test. In tests which are completed in a very short time, such as this one (1/100 second), it is unlikely that any significant changes in resistance will ensue as a result of heating effects. It is advisable, therefore, to use the C type or iso-elastic wire with the higher gage factor. In most impact measurements the higher coefficient-of-resistance change with temperature of the C gages can be tolerated because of the short duration of the test.



FIGS. 13 and 14. *Effect of the natural frequency of a weighing system on the true load-deformation curve.*

For the mount to which the iso-elastic wire is bonded, a hollow tube has been chosen for this measurement. Two main factors are considered in the selection of any mount—first, the available sensitivity, and, second, the natural frequency. In the particular test under discussion maximum sensitivity is necessary in order to test fabrics of low tensile strength, and the tube is ideally suited for this. It is true that a cantilever beam can be designed which is extremely sensitive, but poor natural frequency characteristics usually preclude its use. With a test duration as short as 1/100 second the natural frequency of the weighing system must be relatively high—in this case above 10,000 cycles per second. The necessity for keeping this frequency at a high value can easily be seen if we briefly derive the equation of motion of the mount with the jaw mass attached to it. Consider the system to be composed of a simple undamped spring, in this instance the hollow tube, in series with a known mass—the top jaw. Then let us assume that the applied force F is a linear function of the time variable, t; that is: $F = ct$.

Since the tube can be treated as a simple spring, the restoring force P is given by the familiar Hooke's Law relationship: $P = kx$, where k = stiffness constant, and x = displacement.

The equation of motion is:

$$F - P = m\frac{d^2x}{dt^2}$$

or, by substitution,

$$ct - kx = m\frac{d^2x}{dt^2}$$

or transposing and using the standard differential equation form:

$$\frac{d^2x}{dt^2} + \frac{kx}{m} = \frac{ct}{m}$$

Solving the above equation for x and substituting ω_n, the natural frequency for $\sqrt{k/m}$ yields:

$$F = ct - \frac{c}{\omega_n}\sin \omega_n t \qquad (11)$$

Thus from the above equation, since the term ct represents the true function which should be recorded, the second term, which is a function of the natural frequency, will be responsible for any distortion. With the natural frequency term appear-

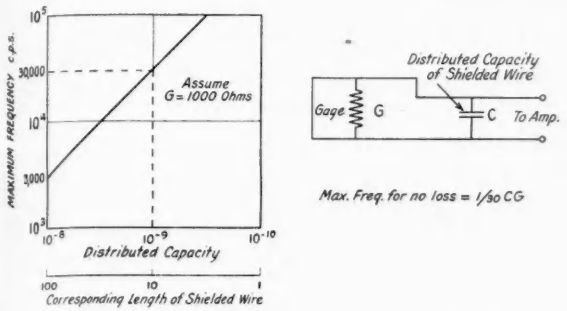


FIG. 15. *Effect of external wiring on the response of a strain gage electrical circuit.*

ing as it does in the denominator, it is desirable to have it as large as possible to minimize this term.

Examination of Figures 13 and 14 will further emphasize the importance of this equation.

In Figure 13 the actual forced motion (ct) is badly distorted by the free vibrations curve, whereas in Figure 14, where the ω_n is considerably larger, the resultant curve is cycling, but lies much closer to the true curve.

In the impact case being considered, the natural frequency of the tube mount is about 10,000 cycles per second. It follows that the stiffness (k) of the tube must be high and consequently the strain, and therefore the percent change in resistance of the gage mounted on it, will be low. As a result, amplification of the signal from the gage is necessary, and it follows that the amplifiers used must have suitable frequency response and linearity characteristics in order that no distortion will result at this point. Similarly, the recording system must also meet the frequency response and linearity specifications.

B. Electrical Circuit. Of the several types of electrical circuits available, into which the strain gages can be built, the circuit used in this dynamic problem is the single gage with ballast circuit. This particular circuit was chosen because of the effect of bending on the weighbar itself. It is possible that the force applied to the end of the tube will not be exactly in line with its axis, which will result in bending stresses. These stresses, unless compensated for, are apt to be of the order of magnitude of the applied stress and seriously to affect the results. Therefore, it is desirable to bond one continuous length of wire uniformly spaced around the entire surface of the tube in order that possible bending stresses be canceled out. Thus, since a single length of wire is desirable, the gage ballast circuit having one gage was chosen.

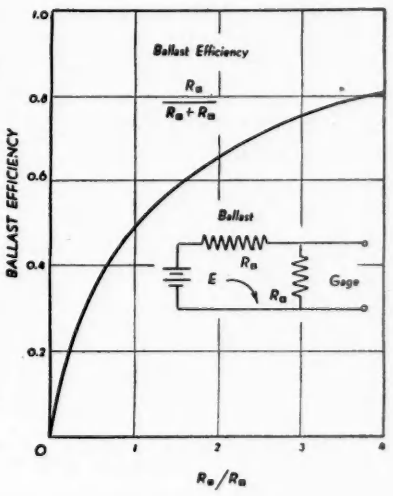


FIG. 16. *Ballast efficiency.*

Consideration of the actual value of the gage resistance is based on its effect on the response of the external circuit, for, once having constructed the weighbar to have the desired natural frequency, it is important that the signal remain undistorted by this circuit. Figure 15 indicates the effect of the external wiring on the response. The lead wires act as a distributed capacitance in parallel with the gage and limit the response, as shown by the graph to the left of the drawing.

For example, assuming a gage resistance of 1,000 Ω and a length of 10 feet for external connections, the response of the gage, independent of its dimensions, would be limited to 30,000 cycles per second.

The gage resistance having been set, the ballast value can be determined by examination of equation (6), which relates the signal produced to the change in gage resistance.

It is evident that a maximum change in voltage will result when the value of the ballast resistor is large compared to the gage resistance. We might refer to the constant $[R_B/(R_B + R_G)]$ as the ballast efficiency, and if this constant is plotted against the ratio (R_B/R_G) the curve shown in Figure 16 is the result. The efficiency increases slowly beyond 65 percent, making a ratio $(R_B/R_G) = 3$ a good compromise. This then results in a ballast resistance of about 3,000Ω. A compromise must be made because the power supply necessary for large ballast resistances becomes large and impractical.

Summarizing the selection for this impact case: the C type wire was chosen for greatest sensitivity; a tube mount for the necessary frequency response; and the single gage with ballast circuit to minimize possible bending stresses.

C. Recording. A final selection to be made is the type of recording system required to draw an accu-

rate picture of the test result. Considering the high-speed character of the test, a suitable instrument, which will indicate an undistorted signal, is the cathode-ray oscilloscope. These instruments are now available with coupled recording systems, but in the particular problem presented here a special high-speed camera was constructed to give a time axis, as shown in Figure 17. A balanced aluminum drum, shown at the left of the photograph, is driven by a synchronous motor. To the outside of the drum is clipped a single length of 35-millimeter film which passes by a high-speed lens focused on the cathode-ray screen. Knowing certain constants of the machine and camera it is possible to interpret the resulting diagram as the load-extension curve of the sample under test.

D. Applications. It is possible with such a system, after a selection of the proper parts of the measuring and recording systems, to detect the differences in the extensions of three single yarns twisted into one plied yarn. An example of such a measurement is shown by a photograph of three actual records (Figure 18). The top curve is the load-deformation diagram for a 1-pound yarn broken in about 1/100 second. The curve is relatively smooth until it nears the break, at which time a number of the individual filaments having unequal ultimate strains rupture prematurely, causing the brass tube to be set in vibration. Attention is called to the high-frequency vibrations after the sample is broken, which represent the natural frequency of the strain gage system. By counting the number of these cycles for a given length of film it is possible to check the natural frequency as calculated from purely theoretical considerations.

The middle record in Figure 18 is for the same type of yarn but with two samples twisted together. It would be expected that because of variations in ultimate extension of the two singles they would rupture at slightly different times. That this was the case is shown by the continuation of the curve after a sharp drop in load to about one-half the value of the peak. This half peak was to be expected since both samples were of approximately the same tensile strength. The continuation of the test, one more step, is shown in the lower record. Three samples in parallel were ruptured and the expected 1, 2, 3 break at a peak load, at two-thirds and at one-third of this peak, is evident from the curve. An excellent idea of the response of this system is afforded by the fact that the test duration in the case of the three-sample break is approximately 1/100 second and therefore the duration of the recorded extension of the second and third samples after the first yarn broke is of the order of 1/1,000 second.

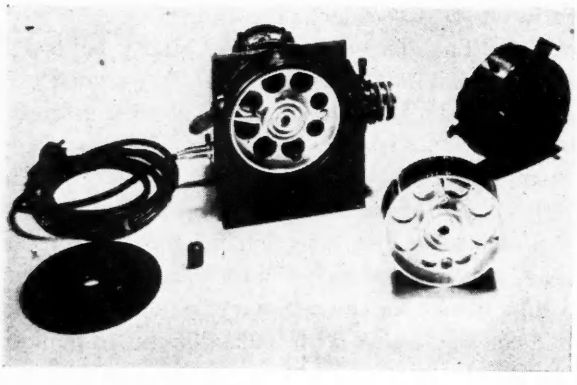


FIG. 17. *High-speed camera specially constructed for recording impact test results.*

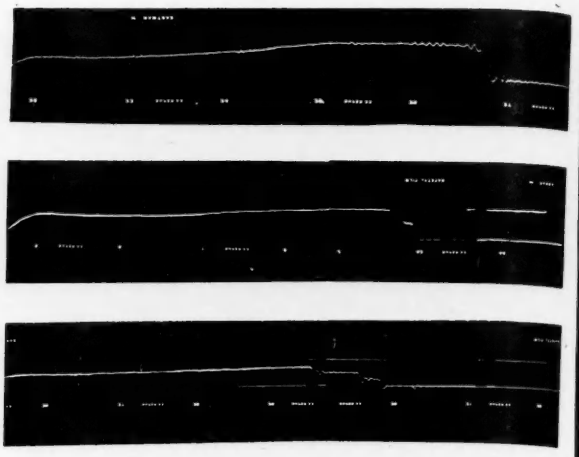


FIG. 18. *Example of response and sensitivity of a properly selected weighing and recording system.*

In order to calibrate the load axis of these curves, a resistor corresponding to a definite load is inserted into the gage circuit, causing the cathode-ray spot to be displaced a distance equivalent to the corresponding load. The result of this calibration operation can be seen in the lower curve of Figure 18 to the right of the film as a set of broken parallel lines.

A result of this impact measurement has been to supply the long-sought answer to the question of the relationship between the low-speed and impact properties of certain textile materials. A comparison of the load-deformation curves resulting from impact and conventional laboratory test measurements is shown in Figure 19. It is evident that the

results are different—in particular, the dip in the impact curve, which is usually not found in a curve obtained at lower speeds.

It should be pointed out that the lower curves resulted from tests on a conventional laboratory pendulum machine which has a great deal of inertia in its moving parts. This inertia might well be the reason for the differences in the shapes of the curves; however, it is unlikely that it could be responsible for the very much lower breaking loads.

With the electrical system of strain measurement described above, which can be applied to slow-speed testing as well as impact, the deficiency of the heavy pendulum, responsible in large part for inertia errors, is eliminated.

Case 2—Slow-Speed Stress Measurement

It is our purpose in the following section to examine the changes necessary for making the slow-speed compressional measurement previously outlined.

A. Weighing System. Since this test requires, in contrast to the impact test, a very much longer time, it is important that, no matter what the electrical circuit is to be, strain gages with a low temperature coefficient of resistance be used. This suggests the A type gage, made of constantan wire, with a slightly lower gage factor than the C type used for the dynamic case. The loss in wire sensitivity is tolerable, however, since it is now possible, with the increase in test time, to use a system of very much lower natural frequency.

We have chosen, as shown, the constant stress cantilever as the strain gage mount. Whereas in the case of the impact tester the weighing system used had an ω_n of 10,000 cycles per second, the mounts used for the resilience tester can have a natural frequency as low as 100 cycles per second. It follows that the system can have a much lower stiffness constant than the tube mount and, as a result, the response will be very much greater for an equivalent load. For example, the fractional change in resistance per pound of force for the gage attached to the tube mount on the impact tester is 2×10^{-5}. For a gage designed to cover the same range on the resilience instrument the corresponding value of $(\Delta R/R)$ is about 2×10^{-3}.

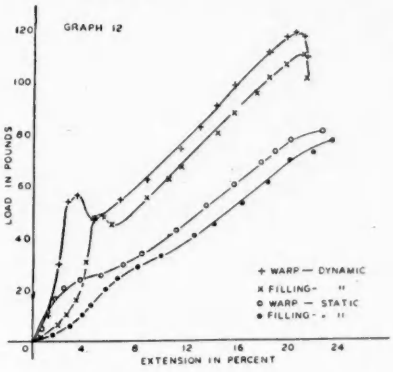


FIG. 19. *Comparison of load-deformation curves resulting from impact and from conventional laboratory test measurements on a textile material.*

B. Electrical Circuit. In the impact measurement the single gage and ballast circuit was used with the tube mount in order to allow the winding of a continuous length of wire, thus insuring cancellation of lateral stress. In the case of the cantilever used here it is unlikely that any stresses other than those at right angles to the long axis will be applied. It is desirable, therefore, to bond conventional commercial gages to the upper and lower surfaces of the lever and if four are used, making up the legs of a conventional D.C. Wheatstone bridge, it is possible to achieve a sensitivity equivalent to that of the single gage circuit. Furthermore, since the tests may run over a relatively long period of time, the use of the D.C. Wheatstone bridge makes it possible to place the gages in such positions as to balance out any undesirable effects produced by changes in resistance due to changes in the temperature of the gages.

It has been found after considerable experimentation that the A-14 gages having a resistance of approximately 500Ω are most efficient from a consideration of sensitivity.

C. Recording. The slow-speed tests run a matter of minutes, in contrast to a fraction of a second for the impact test, therefore precluding the use of the cathode-ray oscilloscope, which is usually limited to either transient or rapidly cycling signals. As a result the recording instrument selected for this test is a photoelectric potentiometer recorder with a very sensitive galvanometer, as the voltage detector. The frequency response of the instrument, although low as compared to the oscilloscope and high-speed camera arrangement, is sufficient for the duration of this test.

D. Applications. Figure 20 (top) illustrates a typical record from the resilience tester of a compression cycle on a single layer of gabardine suiting fabric. Figure 20 (bottom) is a similar record from a cycle applying 10 pounds to a sample of specially treated viscose yarn.

Tests are now under way with this type of instrument to evaluate the many finishing treatments

designed to increase the crush-resistance of fabrics made from the synthetic fibers, as well as to determine the compressional characteristics of napped and pile fabrics.

It should be noted that the curves plotted by most of the voltage recorders have a curvilinear scale for one axis. It is possible, however, with a very simple instrument to replot these into rectilinear coordinates in a few minutes.

Case 3—Measurement of Weight

The electric weighing apparatus is very similar in principle to the compression tester and is presented here as an example of what can be done to increase the sensitivity of the cantilever for measuring extremely small loads.

Weighing, electrical, and recording systems are the same as those used in the case of the compression tester. One of the requirements for the instrument is control of the deflection of the cantilever since it directly affects the resilience curve and has to be evaluated. This correction is simple, however, if the deflection remains small, but beyond a critical value its effect is no longer linear and the correction is difficult, if not impossible, to make. In the measurement of weight, deflection of the cantilever, to a large extent, is no longer a consideration. Maintaining the stiffness constant at a high value, necessary in previous examples to keep the frequency response within a definite range, is unnecessary, and as a result a sensitive weighing instrument will result.

The application made of this weighing measurement has been to record continuously the rate of regain, under standard conditions, of various samples of textile materials which were bone-dried. Figure 21 illustrates a typical curve showing the rate of regain for a sample of cotton yarn which was allowed to absorb moisture after being thoroughly dried. The curve was plotted for a period of 5 hours, showing a gain in weight of 5 grams. The sensitivity of the equipment described above is 0.1 grams per division of the recorder scale. It is possible by the addition of only one stage of amplication of the bridge signal to increase this sensitivity to at least 0.002 grams per division.

Design of Weighbars

It has been shown that the choice of component parts of the measuring system is extremely important for the achievement of any desired result. In this section we will discuss the typical problems confronting the designer of such a system and indicate how these may be solved.

The choice of the proper weighbar, electrical circuit, and recorder has been discussed in detail, but it still remains to determine the dimensions of the weighbar. In order to do this, it is necessary to know the capacity, the sensitivity, the input voltage, and the maximum deflection permissible for a given experiment.

This consideration of deflection enters the calculation whenever it is necessary that one jaw remain fixed. Since the jaw is in series with the weighbar, it is important that the deflection of the weighbar be minimum.

As an example, first let us consider the case of the cantilever beam. From equation (5),

$$f_c = \frac{6P}{kh^2} \tag{12}$$

P is the maximum load capacity for which the weighbar is to be used, and f_c, k, and h are unknowns.

The f_c which should be inserted into equation (12) is that stress which will produce full-scale deflection on the recording instrument. Thus the strain and resistance change to produce full-scale deflection must be known.

Therefore, from equation (8),

$$\Delta V = \frac{E}{2R_G}\Delta R_G$$

or

$$\frac{\Delta R_G}{R_G} = \frac{2\Delta V}{E} = F\frac{\Delta L}{L}$$

or

$$\frac{\Delta L}{L} = \frac{2\Delta V}{FE} \tag{13}$$

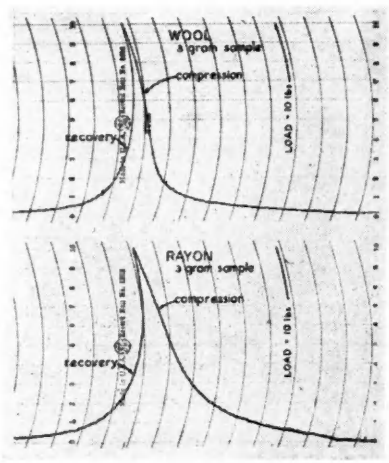


FIG. 20. *Applications of slow-speed stress measurement to textile materials.*

This is for the case of a D.C. Wheatstone bridge circuit with one active leg, a circuit generally used with this type of cantilever weighbar.

The strain given by equation (13), where all the right-hand terms are known, will produce full-scale deflection if ΔV is the voltage required for full-scale deflection of the recorder.

And the stress which will produce this deflection is:

$$f_c = J\frac{\Delta L}{L} = \frac{2J\Delta V}{hE}$$

Substitution in equation (12) yields:

$$kh^2 = \frac{3PFE}{J\Delta V} \tag{14}$$

Since k and h are now unknown, another equation is needed to solve for both simultaneously.

This equation results from a consideration of the deflection equation of a beam:

$$JI\frac{d^2y}{dx^2} = M \tag{15}$$

Here $M = Px$,

$$I = \frac{kxh^3}{12}$$

Therefore equation (15) reduces to:

$$\frac{Jkh^3}{12}\cdot\frac{d^2y}{dx^2} = P \tag{16}$$

and solving (16) for the proper boundary condition yields

$$y_{max} = \frac{6PL^2}{Jkh^3}$$

or

$$kh^3 = \frac{6PL^2}{Jy_{max}} \tag{17}$$

where y_{max} is the deflection at the free end of the cantilever, under the action of a load, P.

Dividing equation (17) by equation (14) yields:

$$h = \frac{2L^2\Delta V}{y_{max}hE} \tag{18}$$

Thus one dimension of the beam is determined. And, substituting in equation (14),

$$k = \frac{3}{4}\left(\frac{Py_{max}^2}{JL^4}\right)\left(\frac{FE}{\Delta V}\right)^3 \tag{19}$$

Thus the beam to meet the specified set of conditions is determined. It is well at this point to check the response of the weighbar.

Such a check involves calculation of the natural frequency. A beam has an infinite number of degrees of freedom; it therefore has an infinite number of natural frequencies. However, the first or lowest natural frequency is the one which determines response, and it can be found by a number of methods, the most generally used being a modification of Raleigh's method and the method of Stodola [4].

All the methods are involved and time-consuming, and experience has shown that a sufficiently good approximation can be made by considering a beam of uniform cross section and applying the formula:

$$\omega^2 = \frac{3.03JI}{L^3(M + 0.23m)} \tag{20}$$

Where I is the average moment of inertia of the sloping beam, M is the mass on the free end, and m is the mass of the cantilever.

If m is small compared with M, the formula

$$\omega^2 = \frac{3JI}{L^3M} \tag{21}$$

proves satisfactory.

In designing a tubular-type weighbar, the procedure is slightly different. In this case frequency response is a more critical consideration and is taken directly into the calculation of dimensions. Because the weighbar must be as light as possible, the tube is designed to the limit of load to be applied with a small factor of safety.

The area of cross section of the tube is expressed by:

$$A = \frac{P}{S_f} \tag{22}$$

where P is the maximum load to be applied to the

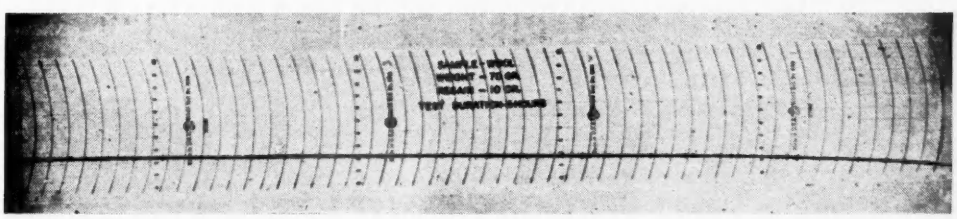


FIG. 21. *Typical curve indicating rate of regain during a 5-hour period.*

tube and S_f is the elastic limit stress. The inside and outside diameters are calculated to give this area, A, and to allow a considerable surface for mounting strain-sensitive wire.

The length of the tube is determined by a consideration of natural frequency, and can be found from the equation

$$\omega = \sqrt{\frac{JA}{L\left(M + \rho\frac{AL}{3}\right)}}$$

where:

ω = minimum allowable natural frequency
A = area found in equation (22)
L = length of tube
M = mass of jaw
ρ = density of tube material

Thus the dimensions are determined. To find the sensitivity:

$$\Delta V = \left[\frac{R_B}{(R_B + R_G)^2}\right] E\Delta R_G$$

$$= \left[\frac{R_B R_G}{(R_B + R_G)^2}\right] EF\frac{\Delta L}{L}$$

$$= \frac{R_B R_G E}{(R_B + R_G)^2} \cdot \frac{FS_f}{J} \qquad (23)$$

Equation (23) gives the change in voltage for the maximum load to be imposed.

Design of other types of weighbars in other types of circuits is followed through in a similar manner, with due regard for the special considerations of the problem at hand.

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Cotton Fiber Imperfections and Their Probable Relation to Yarn Quality

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United States Department of Agriculture

In this paper the common imperfections occurring in cotton fibers have been studied in order to determine (1) the growth factors contributing to the formation of such imperfections and (2) the importance of imperfections as factors which contribute to neppiness in spun cotton.

An analysis was made of several hundred neps occurring in both carded and combed yarns which showed that they were composed of ten different elements. Although there is no conclusive proof that fiber imperfections are the cause of such neps it is shown that more neps contain immature fibers than any other element. It is also shown that fibers of large diameter and deformities are factors which contribute to neppiness and thus to spinning difficulties in greater proportion than their prevalence in cotton would indicate.

THE material presented in this paper has been obtained from the fiber laboratory of the United States Cotton Field Station, Shafter, California. The cotton breeding program at this station requires the routine microscopic examination of large numbers of cotton fibers. The data and illustrations are taken from the records of the crops grown from 1941 to 1943. Most of the data, except those pertaining to neps, represent station-grown cotton.

A review of the literature shows that little work has been done on cotton fiber imperfections. Farr [1], who studied fiber deformities in Pima, Super Seven, and Acala varieties of cotton, concluded that in part, at least, the density of the mass of fibers within the developing boll is responsible for deformities in cotton fibers. In the summary of her paper she states:

"Since the gradient for the increase in density of the fiber mass extends in the same direction as that for increase in the number of abnormalities it is suggested that the density of the fiber mass within the boll during the later stages of development is one of the important factors in the determination of the number of fiber abnormalities found in these three varieties of cotton."

Unfortunately the author did not designate the particular strain of Acala under investigation, for evidence is presented herein which indicates that strains, seasons, and environment have much to do with the formation of abnormalities.

Perhaps the most important, as well as the most frequent imperfection in cotton fiber is immaturity (Figure 1), or the type referred to by Clegg [2] as "dead" fiber. Clegg's differentiation of the three types of fiber—mature, thin-walled, and "dead"—commonly found in nearly all samples so far examined, seems logical and valid. For the purpose of this paper the following terms are defined (fibers treated in 18 percent sodium hydroxide and observed under the microscope):

1. Mature fibers are those in which secondary thickening is so advanced that they appear sharply defined and rod-like.

2. Thin-walled fibers show an intermediate stage in which development was arrested before secondary thickening of the walls was completed.

3. The term "immature" fiber instead of "dead" fiber is preferred. This is the one in that stage of development in which fiber walls are so thin that the natural convolutions remain intact when the fibers are mercerized. The gradation from thin-walled to

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Acknowledgment is made to the California Planting Seed Distributors, Bakersfield, California, for providing assistance for conducting these investigations.

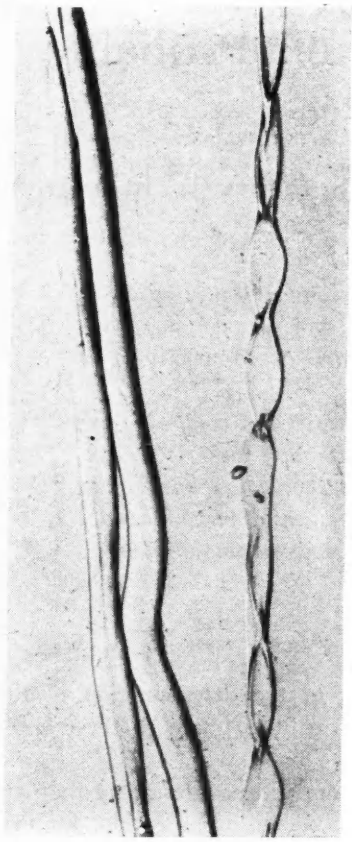


FIG. 1. *Left, fully mature fibers; right, extremely immature fiber. The fiber at the right is the type which is most often found in neps in ginned, but otherwise unprocessed, cotton and in carded and combed yarns. This and all succeeding photographs here shown were taken at 210× after immersion in 18 percent sodium hydroxide.*

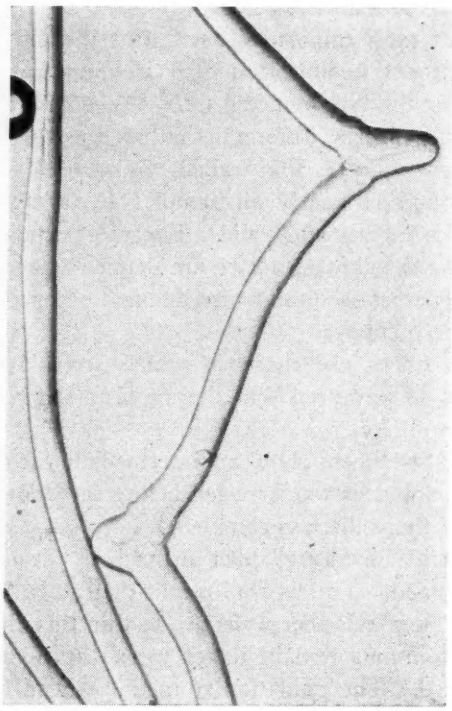


FIG. 2. *Common type of deformities, often occurring in pairs. Sometimes three or even four may be found in a single fiber (dark circle at upper left is air bubble).*

mature fibers is gradual and continuous, making classification difficult. However, the immature fibers are readily distinguishable by the presence of convolutions. In spinning operations thin-walled fibers apparently behave similarly to fully matured fibers, thereby making any differentiation between them seem unnecessary.

Methods

In cotton breeding, selection for improved strains is based on the outstanding plants of a progeny row. These plants are selected on the basis of their appearance in the field. Samples of seed cotton are collected which represent a cross section of the crop produced by each plant selection. Factors, such as location in the row, which might influence fiber quality are recorded.

The size of a sample for laboratory study depends somewhat on the productivity of the plant but varies from about 30 to 60 grams of lint cotton. For tensile strength determinations by the Pressley method 5 to 10 portions of combed lint weighing approximating 50 to 60 milligrams each are removed from the original sample. For microscopic observations two samples of approximately 350 fibers each are removed from the unused lint remaining after the tensile strength determinations. The sample to be examined under the microscope is combed carefully and is then thinly distributed over a 2-by-3-inch slide. The fibers are roughly parallel to each other.

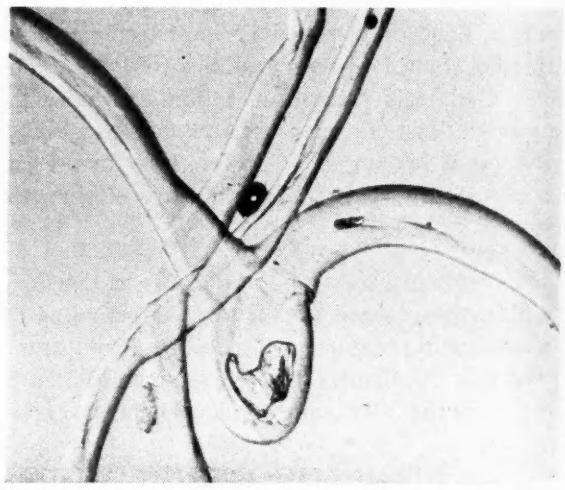


FIG. 3. *A common type of major deformity, often much larger, usually rough and flabby and accompanied by much enlarged diameter for considerable distances. This type is very common in fuzz hairs, often involved in neps.*

with their ends on a fairly straight line. The sample is next covered with another slide the same size as the first. A drop of 18 percent sodium hydroxide solution is applied along the edge of the adjoining slides in such a manner as to immerse all the fibers. The microscope used provides a magnification of 210 × and is equipped with a mechanical stage. Two mechanical counters are used in conjunction with the microscope. This enables the operator to record easily the number of immature and mature fibers, or else the number of major and minor deformities. Maturity counts are made at approximately the midpoint of the fibers. In maturity counts only one observation is made of each fiber, whereas the deformity counts require the examination of the entire length of each fiber. This is accomplished by making as many "trips" across the slide as necessary to cover the length of lint under observation. Deformity counts are expressed as the average number of deformities per 100 fibers. A count of 10 deformities per 100 fibers does not necessarily mean that 10 percent of the fibers are deformed. Two or more deformities often occur on the same fiber, and in routine examination this fact cannot be detected by the operator.

Types of Deformities

The deformities in cotton fibers are classified as either major or minor. The major deformities are those which appear to be troublesome in spinning operations, thereby causing breakage, entanglement, or neps. Such deformities (Figures 2 and 3) are found in many shapes and sizes and usually form an acute angle in the fiber axis. They include branching of the fiber, as shown in Figure 4. Minor deformities (Figure 5) generally consist of enlargements of portions of fiber and are not large enough to cause trouble in handling operations. This differentiation between deformities may at first seem arbitrary, but the examination of several hundred thousand fibers and the complete analysis of the composition of about two thousand neps from spun yarns and woven fabrics points to the conclusion that there is sound basis for designating deformities as major or minor in importance. With some exceptions the ratio between major and minor deformities is about two to one.

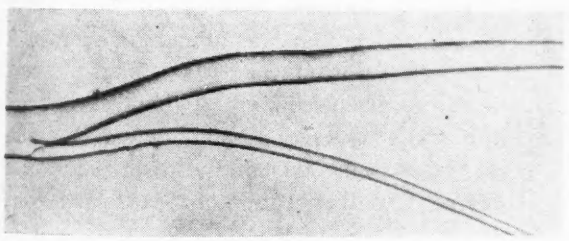


FIG. 4. *An otherwise normal fiber with small branch coming out near middle. Sometimes these branches come out at right angles, or near right angles; rarely, two branches, opposite each other, have been observed growing off a single fiber. One variety has been observed in which this type of growth was fairly common in the crop of 1941.*

Varietal and Strain Differences

In 1941 sixty progeny rows of one variety were grown in the breeding nursery. This particular variety had been used for a number of years as the nucleus for increasing the commercial seed supply.

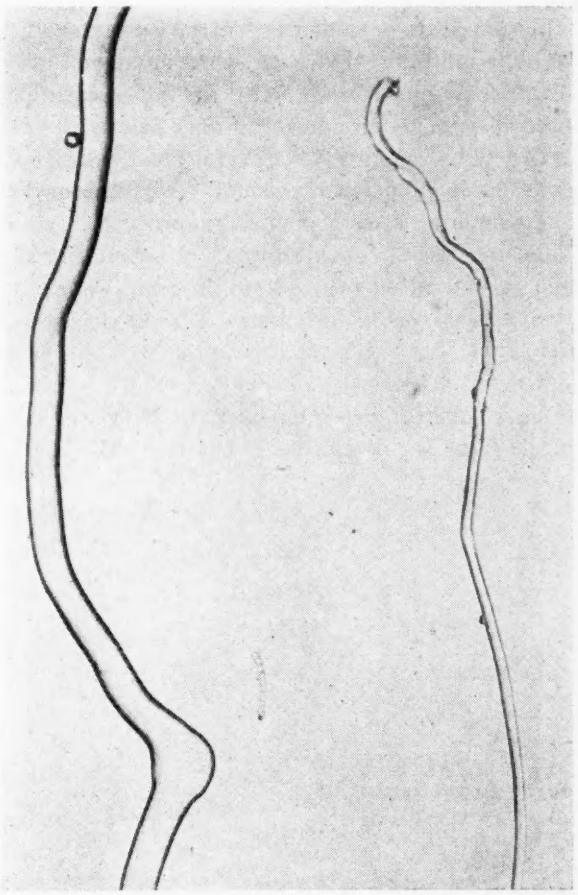


FIG. 5. *Left, minor deformity near middle of fiber. Right, tapered end of fiber showing some of a type of roughness common to distal ends.*

TABLE I. AVERAGE NUMBER OF DEFORMITIES PER 100 FIBERS IN 16 ACALA FAMILIES AND 3 MEADE FAMILIES IN 1942 AND 1943

Family	Number of deformities in 100 fibers	
	1942	1943
Acala P18 C 10 6	8.8	5.4
Acala P18 C 10 39	5.2	1.4
Acala P18 C 10 40	5.7	2.8
Acala P18 C 20 23	17.6	1.1
Acala S 5 4 1 11 9	7.0	1.9
Acala 1517 1 23 11	8.5	4.1
Acala 1517 3 1 42	7.2	1.5
Acala 1517 4 42 44	4.7	1.1
Acala 1517 5 12 7	5.8	2.5
Acala 1517 5 12 36	3.7	2.1
Acala 1517 7 49 1	3.8	1.9
Acala 1517 7 49 5	5.3	1.5
Acala 1517 7 49 14	4.8	3.5
Acala 1517 9 1 6	3.3	1.9
Acala 1517 9 1 13	4.5	2.8
Acala 1517 9 1 41	7.1	2.4
Meade 14 2 28 7	3.5	1.6
Meade 14 2 28 28	4.4	1.1
Meade 14 2 28 34	7.0	1.9

After six years of selfing this variety was thought to be quite uniform. However, an examination of 600 plant selections showed that the above-mentioned progenies ranged in number of fiber deformities from very few to very many. Several plant selections of each grade of deformity count (few, intermediate, and numerous) were planted in progeny rows the following year. The progenies grown in 1942 in general resembled their parent progenies in the relative numbers of deformities. A plant having few deformities would produce a progeny also having few deformities.

Fiber deformity counts made in 1941 were on a grade basis, as noted above, but in 1942 the count was made on a numerical basis. Table I shows the mean numbers of deformities in the different families as determined in 1942 and 1943.

TABLE II. EFFECT OF POLLINATION TREATMENT ON SEED SET AND DEFORMITY COUNT—1942

Treatment	Average number seeds per boll	Average number motes per boll	Deformity count		
			Seed tip	Seed base	Average
30 grains pollen	12.2	13.7	8.62	6.62	7.62
60 grains pollen	17.6	13.5	15.13	10.73	12.93
Open pollinated	39.6	6.4	27.80	14.40	21.11

The deformity counts listed in Table I were made on fiber populations ranging from about 5,000 to more than 50,000 fibers. Family P18 C 20 23 is worthy of particular attention because it had a high number of deformities in 1941. The 1942 counts verified the previous findings. However, this particular family had one of the lowest counts in 1943. At first it did not seem possible that such a difference in deformity count could occur in one family during two seasons. Growing conditions during both seasons were considered to be satisfactory, although the mean temperature during the period when cotton fibers were developing was about three degrees lower in 1943 than in 1942.

Hemipterous insects, which often feed on tender cotton bolls, were much less troublesome in 1943. However, there is no experimental proof that these insects are in any way responsible for fiber deformities. These insects are responsible for immature fibers, a fact that can be detected without the aid of a microscope. Fibers produced in that part of the boll which is near an insect feeding puncture show a high degree of immaturity.

During two seasons at Shafter one strain of Sea Island cotton was found to average less than one deformity per 1,000 fibers. The deformities produced were, without exception, of the major type, unusually long and confined to the extreme tips of the distal ends of the fibers. Another strain of Sea Island cotton

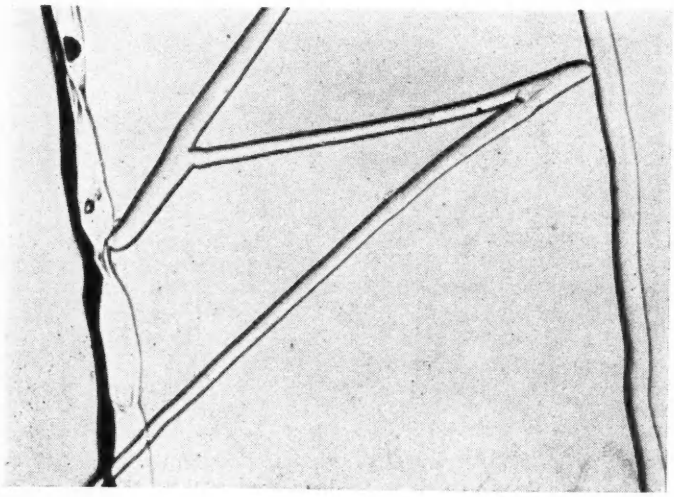


FIG. 6. *Major deformities near distal end of a fiber. A third one of this same type occurred in this fiber, but too far removed to be included in the picture (dark line at left of picture is an air bubble).*

TABLE III. EFFECT OF POLLINATION TREATMENT ON SEED SET AND DEFORMITY COUNT—CROP OF 1943

Treatment	Average number seeds per boll	Average number motes per boll	Deformity Count Seed tip	Seed base	Average
30 grains pollen	11.2	10.0	4.57	4.47	4.52
60 grains pollen	17.9	12.4	7.00	6.05	6.56
Open pollinated	40.8	5.0	8.53	5.26	6.80

having somewhat shorter fiber but growing in high alkali plots at the U. S. Regional Salinity Laboratory, Riverside, California, was not materially influenced by the soil medium. Under these conditions the number of deformities per hundred fibers ranged from 1.25 to 3.93 and these were distributed at random throughout the length of the fibers. The location of deformities on the fiber may be characteristic of a strain, as noted above. Strains which tend to have relatively few deformities are more likely to have them confined to the distal ends (Figures 6 and 7).

Effects of Density of the Fiber Mass Within Bolls

If cotton could be grown with fewer seeds per boll than normal, it might be possible to discover what influence the density of fiber mass has on the formation of deformities. In 1942 a number of flower buds were emasculated and then pollinated with 30 or 60 grains of pollen from the same strain. Each treatment was repeated on 40 flowers from 40 consecutive plants of a single row. Other flower buds were marked with dated tags and allowed to develop naturally. These served as a check on the treated buds. The flower buds pollinated with 30 grains of pollen produced 8 bolls and those pollinated with 60 grains of pollen produced 15 bolls, whereas all the check buds produced bolls. The results of the different pollination treatments on fiber deformities are given in Table II.

The two sets of bolls from the buds which received pollination treatment showed a marked deficiency in seed setting as compared with the check bolls from the open-pollinated buds. The fewer seeds of the treated bolls had more room to develop and consequently produced a mass of lower density than that of the check bolls.

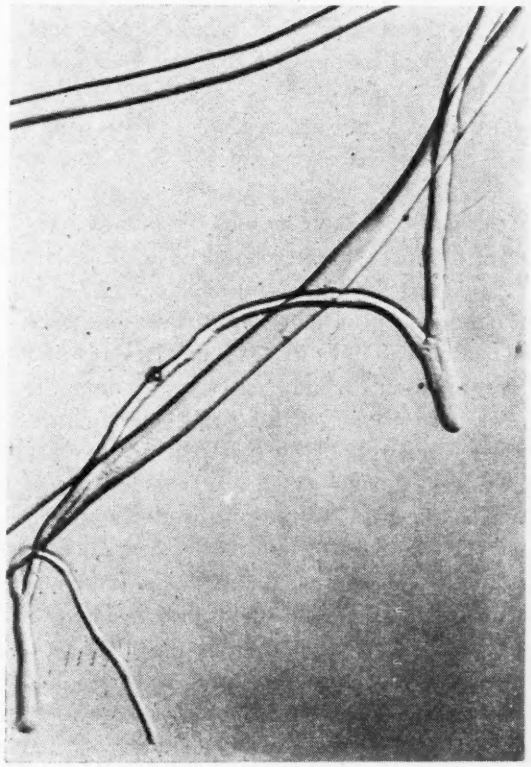
FIG. 7. *Distal-end deformity. This type often breaks in one angle or the other in handling fiber and accounts for some of the fragments found in neps.*

TABLE IV. NUMBER OF DEFORMITIES AND IMMATURE FIBERS AT TWO LEVELS OF IRRIGATION (FOR 1942 AND 1943)

Year	Treatment and series	Deformities per 100 fibers	Immature fibers (%)
1942	Dry I	9.22	3.65
1942	Dry II	8.45	4.72
1942	Wet I	9.50	3.21
1942	Wet II	9.04	4.31
1943	Dry I	8.82	13.52
1943	Dry II	12.67	11.91
1943	Wet I	7.62	7.35
1943	Wet II	5.34	6.54

To establish more conclusively the relation of boll density to fiber deformity counts, the above experiment was repeated in 1943, using the same lot of seed. The results of this test are given in Table III.

The number of bolls produced by each pollination treatment in 1943 was similar to the number produced in 1942. The main point of difference was the significantly lower deformity count for the bolls from the buds subjected to the 60-grain treatment, as well as for the check bolls in the 1943 experiment. This appears to be a seasonal difference and agrees with other observations made during these two years.



Effect of Environment on Fiber Imperfections

Soil conditions such as unlevel land, areas of poor permeability, or low water-holding capacity may cause imperfections in the cotton fiber. The effect of such detrimental soil factors on the amount of immature fiber has long been recognized. Cook and Willis [3] recommended that areas with poor soil conditions be segregated at harvest time. Data presented in Table IV indicate that the amount of immature fiber may be substantially increased without altering perceptibly the appearance of the field at maturity or reducing the aggregate yield.

The data in Table IV were compiled from a test designed to determine the effect of certain irrigation practices on fiber characteristics. In the dry treatments only enough water was supplied to prevent the cotton plants from dropping an abnormal amount of the crop. At the other extreme, the wet treatments supplied an abundance of water regardless of requirements. In both treatments the soil was irrigated to capacity before seeding, and about June 20 both were irrigated alike. Thereafter the plants under dry treatment were irrigated only when half of the plants showed wilting at mid-day. Irrigation was discontinued entirely about September 8 for the plants receiving the dry treatment. Those under wet treatment were irrigated every eighth day from June 20 to September 20. It is estimated that the plants subjected to the dry and wet treatments received about 20 and 40 acre-inches of water respectively after the cotton was seeded. In 1942 the yield of seed cotton was the same for both treatments. The yield in 1943 was only slightly higher for the wet treatment. In both seasons the heavily irrigated plots were slower in maturing. The difference in date of opening for bolls of similar age amounted to about one week until the end of the season, when the difference was 30 days in 1942 and 12 days in 1943. The continuation of high temperatures into the autumn of 1943 accounted for the earlier maturity of the wet-treatment bolls for that year.

The period during which a boll develops and the location of the plant in the plot were thought to influence the character of the fiber. Accordingly, two series of 25 consecutive plants were staked off in both the dry- and wet-treatment plots. The Series I plants were located in the upper third of the plot, and the Series II plants in the lower third of the plot. All flowers produced on each series were identified by a dated tag on the day of opening. At harvest time the flowering period was divided into 5-day intervals. Twenty-boll samples, of not more than one boll per plant, were picked for each 5-day flowering period.

For the year 1942 there were no significant differences in the number of fiber imperfections for the various treatments. An important fact, not shown in the above table, is that the peak of deformity formation in the dry series occurred during the last week of the season in which bolls were set. In the wet series, however, the peak in the formation of deformities was reached about 20 days earlier and was about 15 days in duration. The percentage of immature fibers for both series fluctuated slightly throughout the season.

The results for 1943 given in Table IV show that the irrigation treatments had a significant effect on both the deformity count and the percentage of immature fibers. The difference between the series for each treatment is probably due to their location, although unobserved contributory causes, such as injury by insects, may have played a part. Throughout the season the fluctuation in number of deformities and in immaturity was confined to rather narrow limits, more so than in the previous crop.

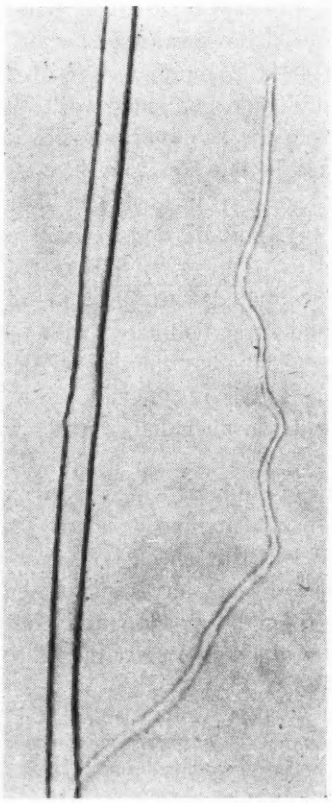


FIG. 8. *Left, mature fiber, diameter a little small; right, fully mature fiber tapered to extremely small diameter. This represents about the extreme in tapering so far observed in any cotton.*

Other studies conducted during recent years show that fiber deformities are definitely inherited. Data presented in Table I indicate that the season exerts considerable influence, and those in Table IV show that irrigation practices contribute to the formation of fiber abnormalities.

Other Imperfections in Cotton Fibers

In addition to deformities and immaturity, there are other fiber imperfections worthy of consideration. Of first importance is the condition of the fiber known as extreme tapering (Figure 8). The taper in normal, well-developed fiber becomes noticeable near or beyond its mid-point and continues to the distal end. In some instances tapering is more abrupt than usual and an extremely fine fiber is produced. There is some evidence that extreme tapering is due to adverse growing conditions. This is well illustrated by Peebles and Fulton [4] in a report on fiber imperfections of ratooned S X P cotton. Eighty-two percent of this cotton showed extreme tapering as compared to 50 percent for annually grown cotton of the same variety. Peebles states that "ratooned yields are often curtailed by insufficient or improper irrigation."

FIG. 10

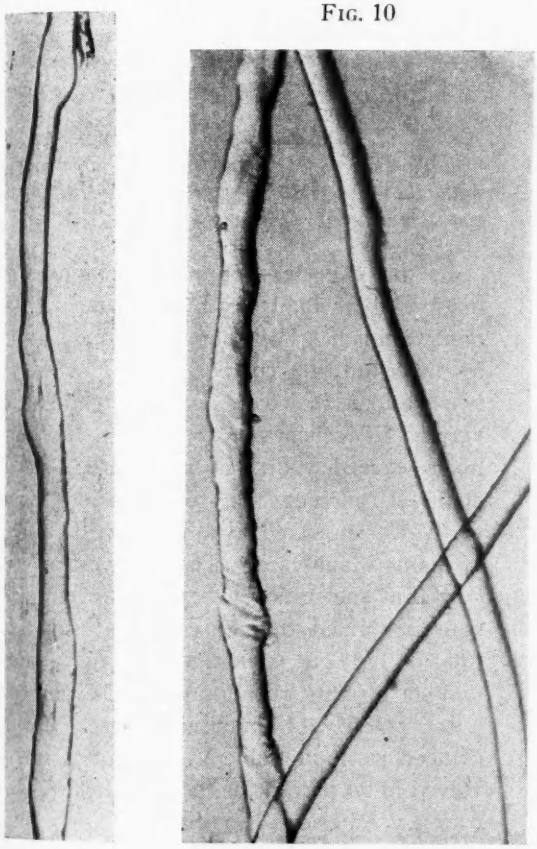


FIG. 9. *Fiber with rough walls, found only on fully mature fibers, a condition believed to be associated with adverse growing conditions such as moisture deficiency.*

FIG. 10. *Left, roughness similar to that shown in Figure 9, but complicated by sand cuts. This condition is often found when sand is not present, but appears to result from leaf and stem trash. Right, well-matured fiber with smooth walls.*

TABLE V. ORDER OF OCCURRENCE OF THE 10 ELEMENTS FOUND IN THE NEPS OF CARDED AND COMBED YARNS, AND THE PERCENTAGES OF THE TOTAL NEPS IN WHICH EACH ELEMENT WAS INVOLVED (CROP OF 1943)

	Analysis of 460 neps Carded yarns (36s)		Analysis of 400 neps Combed yarns (80s)	
Elements	Number neps involved	Percentage neps involved	Number neps involved	Percentage neps involved
Immature fibers	424	93	376	94
Mature fibers	396	86	264	66
Thin-walled fibers	330	72	300	75
Extreme tapering	328	71	292	73
Fiber roughness	289	63	284	71
Seed coat	277	60	232	58
Large-diameter fibers	256	56	232	58
Deformities	233	51	164	41
Fuzz hairs	183	40	148	37
Fiber fragments	85	18	124	31

Fiber roughness, as illustrated in Figures 9 and 10, has been observed only in fully mature fibers. Although it may be found at any point of the fiber axis, it is more likely to occur near the distal ends. Roughness has been found in all cottons examined, but it is more likely to occur in the shorter-staple varieties having the so-called hard-bodied fiber. Limited soil moisture is known to increase the amount of roughness. Whether fiber roughness is objectionable is still to be determined, for it has been found abundantly in some of the strongest and smoothest yarns examined.

Large-diameter fibers are troublesome. Because they have been found in more than 50 percent of all neps so far analyzed (Table V), they are thought to be one of the contributing causes of neppiness. In 1943 their presence in neps varied widely between varieties and within varieties at different stations. Large-diameter fibers (Figure 11) are usually of the same length as the normal fibers in the sample and are not to be confused with fuzz hairs, many of which are equally large. If the fibers are fully mature, the walls are usually in proportion to their diameter. No reason for the large size of these fibers has ever been observed. Moreover, they are likely to occur in all varieties and under all conditions of growth. Large-diameter fibers are never very numerous; only rarely have they constituted more than 1 percent of the sample.

Possible Importance of Fiber Imperfections

Although fiber imperfections are frequently found in the neps of spun cotton, there is as yet no conclusive proof that they are the cause of such neps. An analysis of several hundred neps showed that they were composed of ten different elements, as listed in Table V. The neps were removed from the yarn as it was unwound off the reel. They were then immersed in 18 percent sodium hydroxide solution and examined under the microscope at 210 ×. The samples making up this study represent, for the carded yarns, six varieties grown at five stations, from California to South Carolina. The combed yarns represent twenty varieties grown at five stations, from Arizona to South Carolina in connection with the Federal-State Cotton Breeding and Improvement programs.

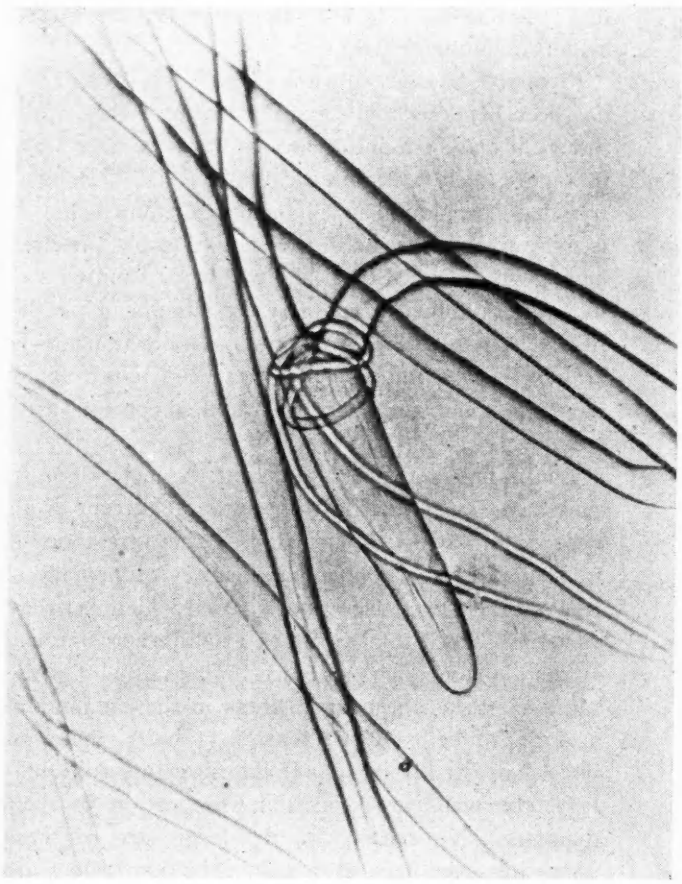


FIG. 12. *Illustrating how extreme tapering and deformities may become entangled. This would likely have formed the nucleus for a nep had this cotton been spun. The major deformity, near the middle of the fiber, is fairly common in some varieties.*

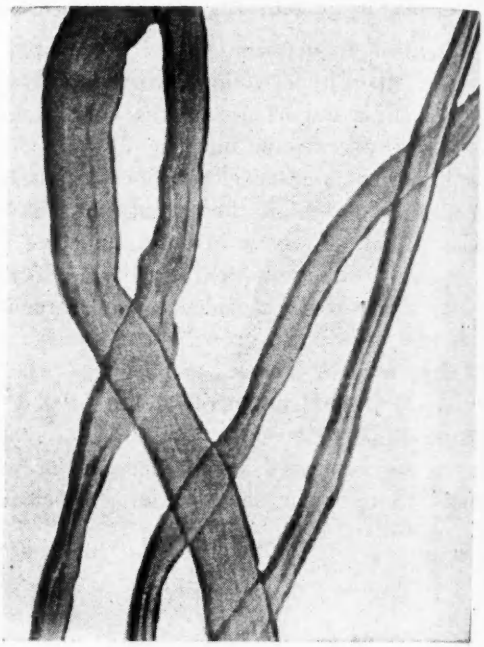


FIG. 11. *Illustrating large-diameter fiber, usually with very thick walls, in comparison with those of normal size. Picture taken at about middle of all fibers.*

As was expected, more neps contained immature fibers than any other element. This observation has been noted in previous studies made on nep composition. However, at two stations an exception was noted for one variety in which the frequency of mature fibers exceeded that of immature fibers by about 10 percent. At some stations immaturity was involved in more than 99 percent of the neps analyzed. The other extreme occurred at one station, where 83 percent of the neps contained immature fibers. Out of a total of 1,990 neps examined in two years, a number of neps were found which were composed entirely of immature fibers. For the combed yarns in Table V immaturity was involved in 94 percent of the neps from Upland cotton. American-Egyptian (S × P) cotton when grown in Florida in 1943 showed 87 percent and when grown in Arizona in 1942 showed 95 percent. The thought that immature fibers are of primary importance is based on the fact that they are found in relatively low percentages in well-grown cottons and that they are involved in more than 80 percent of the neps of the best carded yarns.

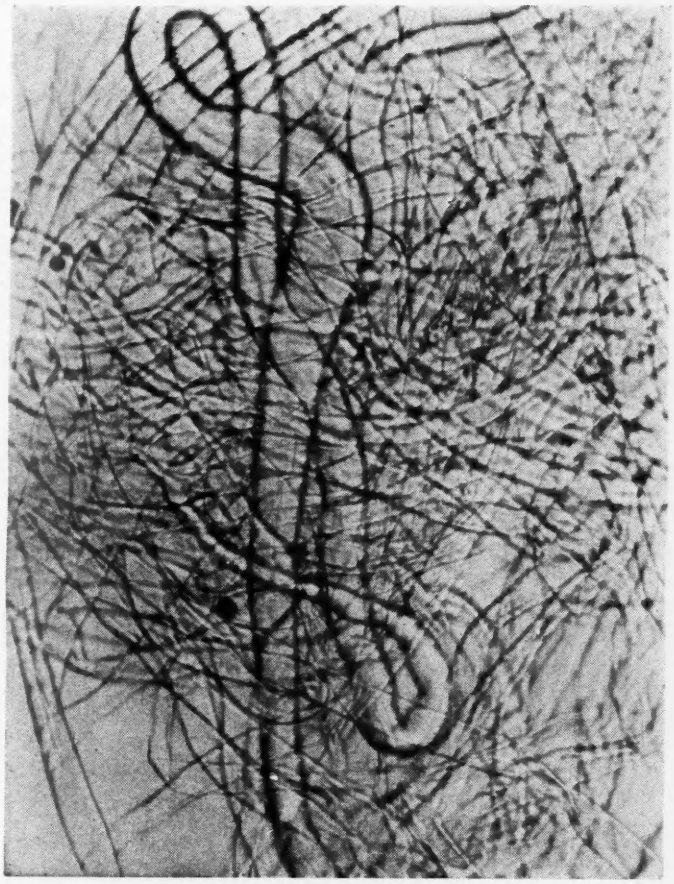


FIG. 13. *A single fuzz hair forming the core of nep which is otherwise composed of immature and thin-walled fibers. This nep taken from a spun yarn.*

In an average season at Shafter immature fibers in well-grown cotton seldom exceed 10 percent. In 1943 the average of 252,000 fibers examined in the breeding program was 4.45. It must be noted, however, that in the breeding work bolls which open at the end of the season are not sampled. Uninjured bolls opening late in the season may exceed 18 percent immaturity.

Mature and thin-walled fibers cannot, by themselves, be classed as abnormal or imperfect. In all cotton examined it has been found that the thicker-walled fibers occur at the micropylar end of the seed, and the thinner-walled fibers near the chalazal end. Mature and thin-walled fibers seldom occur by themselves in a nep. They are almost always associated with other elements. Both the mature and the thin-walled fibers absorb sodium hydroxide solution readily, in contrast to its slow absorption by immature fibers.

It has been suggested above that extreme tapering, fiber roughness, fibers of large diameter, and deformities are factors which contribute to neppiness, and thus to spinning difficulties, in greater proportion than their prevalence in cotton would indicate. This is verified by the figures in Table V, which show the frequency of occurrence of each element in neps of both carded and combed yarns. Excess tapering and deformities may be associated in the formation of neps. In Figure 12 a finely tapered fiber is entwined in the crotch of a deformity. This can also happen with fibers of full diameter, but observation shows it to be less likely. Neps are often composed of a large-diameter fiber surrounded usually by a mass of immature fibers. The number of large-diameter fibers in any given sample is very small in relation to the other elements, noted above, which are found in neps. Large-diameter fibers constitute less than 1 percent of

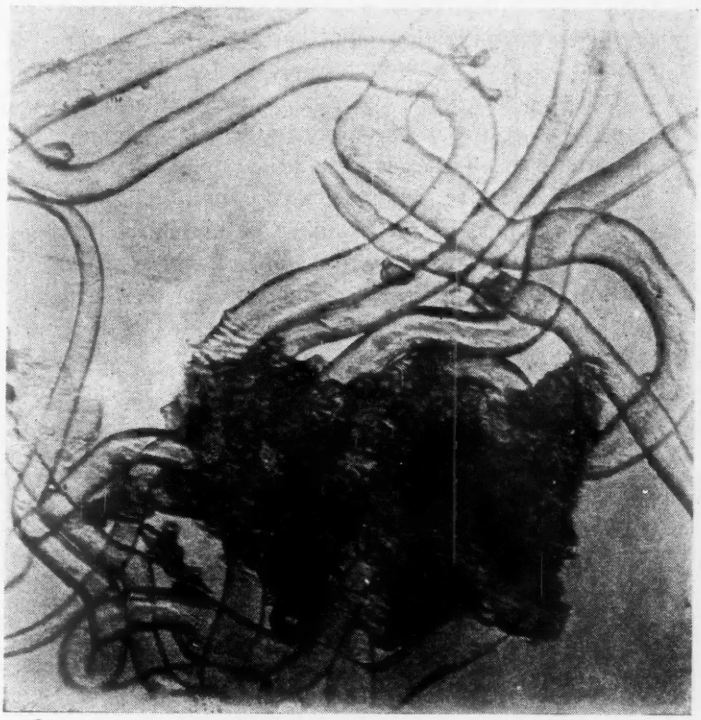


FIG. 14. *Seed coat particle with fuzz hairs attached.*

the fibers, but in the 1943 crop they were found in 57 percent of all neps examined.

Fiber roughness, illustrated in Figures 9 and 10, is not uncommon in fully mature cotton. As indicated in Table V, roughness occurred in 71 percent of the neps of combed yarns and 63 percent of the neps of carded yarns. It is not known just what role fiber roughness plays in nep formation. It occurs under all conditions and so generally that it is difficult to determine what causes it.

Seed coat particles and fuzz hairs, though not regarded as fiber imperfections, are of such common occurrence in neps that they deserve mention. The cotton breeder, as well as the grower and the processor, have it in their power to eliminate much of this foreign material from cotton lint. Strains of cotton can be developed in which the chalazal cap, or the portion of the seed coat usually found in neps, is more firmly attached to the seed. Progeny lines should be eliminated in which the raphe protrudes above the surface of the seed coat. The amount of long fuzz on the seed can be materially reduced without sacrificing the quantity of desirable fibers. The grower and the ginner can reduce the amount of seed coat and seed fuzz in cotton by harvesting only dry cotton and insisting upon good ginning. The fact that about 60 percent of all neps contained seed coat particles and about 40 percent had fuzz hairs clearly shows that once these two elements have been incorporated into the cotton bale there is little that the spinner can do to remove them. If either seed coat particles or fuzz hairs come in contact with immature fibers in any of the usual mechanical handling operations the formation of a nep, as illustrated in Figures 13 and 14, is almost a certainty. This has been determined by the examination of ginned, but otherwise unprocessed, cotton, and by analysis of the neps. Mature fibers which adhere to the seed coat particles no doubt contribute to neppiness, but there is little reason to believe that they would do so if free from the seed particle.

Fiber fragments found in neps are probably a product of the various handling operations. Repeated observations indicated a tendency for fibers to break in the vertex of the angle in major deformities, and, thus, that fiber deformities contribute to fragmentation. For a deformity having an acute angle near the distal end of the fiber the probability of breaking would be high. The proportion of neps containing fiber fragments varies widely. In Table V it will be seen that 18 percent of the neps in carded yarns contain fragments. This condition is comparable to results obtained in 1942 on a similar but smaller population. However, in 1943 a sample of carded yarn from one station showed only 1 percent of the neps to contain fiber fragments. A sample of combed yarn from the same station the same year had fragments in 38 percent of the neps. Though there may be varietal differences, handling operations, particularly combing, contribute most to the formation of fiber fragments.

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Book Reviews

The Measurement of Color. W. D. Wright. Published by Adam Hilger Limited, London, N.W. 1, November, 1944. 223 pages, 65 illustrations. Available in this country from Jarrell-Ash Company, Boston, Mass. Price, $9.75.

(Reviewed by Dorothy Nickerson)

Dr. W. D. Wright, an outstanding British authority on color, describes in this book the principles, methods, and applications of the trichromatic system of color measurement, particularly as it relates to the system of the International Commission on Illumination. He intends the book to be an introduction and guide to the great variety of original papers on color which have been appearing in recent years. It is an excellent handbook for the student.

The "vexed question of terminology" is raised in the preface, and the reader is informed of recent progress made in this field by the two committees actively engaged in its standardization: first, the Colorimetry Committee of the Optical Society of America, appointed in 1933 (sections of its report have now appeared in the *Journal of the Optical Society*); and, second, a committee appointed in 1941 by the Colour Group of the British Physical Society.

In seven chapters Dr. Wright discusses radiation in the visible spectrum, its emission, absorption, and reflection; radiation and its reception in the eye; the trichromatic system of measurement; colorimeters—their design and use; spectrophotometry as applied to the measurement of color; the color atlas as a substandard of color measurement; and practical applications of colorimetry.

Chapter III might be considered the most important of the book. It will undoubtedly clear up for many students the meaning and importance of the I. C. I. (or C. I. E.—Commission Internationale de l'Eclairage) method in relation to the "trichromatic" system. The general problem is illustrated diagrammatically, and transformation equations are given which illustrate how one may transfer from one set of reference stimuli to another. The position and shape of the spectrum locus is discussed, as well as the derivation of the trichromatic equation from the energy distribution curve. This leads logically to a description of the reasons for adopting the I. C. I. equation in its present form. Basic tables are included, and, in addition, a discussion and tabulation of data for the three standard I. C. I. illuminants.

General principles of trichromatic additive colorimeters are supplied, with diagrams and descriptions of the Guild, Wright, and Donaldson instruments. Guild's vector method of locating a color in the chromaticity diagram is included. There is also material concerning measurement on a monochromatic-plus-white basis, subtractive mixtures (including the Lovibond Tintometer), principles of photoelectric tricolorimeters (including the Blancometer), and physical colorimeters employing a spectrum and mask device.

Considerable optimism about the future role of spectrophotometry in color measurement is expressed by the author, yet he does his readers a real service in devoting much of one chapter to pointing out the many precautions necessary before a reliable energy curve can be recorded. Several instruments are described, both visual and photoelectric: the Guild, Hilger-Nutting, Preston and Cuckow, and the Hardy spectrophotometers.

The chapter on the place of a color atlas in color measurement is well presented. Several color charts are mentioned—the Munsell system being described in detail—with reference to the work carried out in recent years by colorimetrists and psychologists in the United States. A section on disc colorimetry indicates the use of this method when visual reference to charts is not sufficient, and the statement is made that in the United States there seems every reason to believe that disc colorimetry, used in conjunction with the Munsell system, will constitute an important phase of color measurement, and that, with the continued standardization of the Munsell chips, it may in some cases prove an adequate substitute for the other types of visual colorimeters which at present are more widely used in Great Britain.

The final chapter, on applications, is one that will interest every reader, for it covers a wide variety of subjects, from the coloring power of chemicals to dichroism as it affects measurements of blood color. Included in the Appendices is a minimum of tables to provide necessary computational data for the I. C. I. method of specification.

Until after the war and the publication of the

O. S. A. report in book form, the Wright book will probably be the only one that brings this subject up to date. It will serve as an excellent introduction to this field.

Commercial Methods of Analysis. Foster Dee Snell and Frank M. Biffen. New York, McGraw-Hill Book Co., Inc., 1944. vii + 753 pages. (In International Chemical Series.) Price, $6.00.

(*Reviewed by C. R. Bragdon*)

In this age of specialization and tremendous diversification of new products, every chemist, no matter how expert in his own particular line, is occasionally confronted with an "unknown" substance or composition that requires unfamiliar techniques of analysis. This book brings together in a compact, well-written volume the detailed procedures for handling most such problems, whether for the purpose of comparing with competitive products, of determining quality, or of forming a basis for manufacture of a similar product (each of which requires a different approach).

Many of the methods are those of the American Society for Testing Materials or the Association of Official Agricultural Chemists, often reworded for simplicity; many have been developed and thoroughly tried in twenty years of the authors' commercial laboratory experience. Emphasis is given to directness of operation, with the degree of accuracy adequate for the desired purpose. Necessary preliminary steps, and those of the actual analysis that are not self-explanatory, are clarified, and much attention is given to interpretation of results, a feature lacking in so many analytical textbooks.

Beginning with four chapters on general procedures, tools, and preliminaries, and one on the new qualitative micro and spot tests, the book next deals with pH determination and electrometric titration, and with the methods for halogens, combined nitrogen, sulfur, and sulfur compounds, which are incidental to so many varieties of products. It then takes up the various specialized fields in a series of twenty-nine chapters covering the whole range of modern industrial chemistry. Of special interest to the textile technologist are the six chapters devoted to fats and oils, sulfated oils, lubricating greases and waxy substances; two to protective coatings and resins; three to pigments and filters; one to emulsions; two to rubber and elastomers; and one of 40 pages, illustrated with a number of photomicrographs, to paper, paper and textile fibers, and starches. A final chapter treats of indicator, reagent, and volumetric solutions.

While particularly valuable to the novice in a commercial or industrial laboratory, this book will be often helpful to the more experienced analyst who must venture into strange fields, and who will seldom fail to find proper guidance in it.

Plastics Catalog—The 1945 Encyclopedia of Plastics. New York, Plastic Catalogue Corporation, 1945. 1,178 pages. Illustrated with drawings, photographs, and charts. Price in U. S. A., $6.00.

This is the ninth edition of the *Plastics Catalog*, an impressive volume which is truly what it purports to be—an encyclopedia of plastics. It contains all of the basic information which one might reasonably need on the subject of plastic materials, their manufacture, their fabrication, and their many uses, with particular emphasis on the industry's wartime advances.

There are sections on the following subjects: progress in plastics; technical data; materials; engineering design; molding, extruding, and casting; fabricating, finishing, and assembly; machinery and equipment; laminates, plywood, and vulcanized fiber; coatings; synthetic fibers; synthetic rubbers and rubber-like plastics.

There are nine charts devoted to plastics identification, plastics properties, chemical formulas of plastic resins and synthetic rubbers, the manufacture of plastics materials (flow charts), solvents, adhesives, plasticizers, plastics used in liquid coatings, and properties of synthetic rubber.

The book includes a complete directory of the plastics industry—educational institutions; suppliers of raw materials, machinery, and equipment, with information on the plants and personnel of each; molders; laminators, fabricators; and extruders—with a complete alphabetical list of every known factor and supplier in the industry.

The 1945 edition of the *Catalog* has been revised and expanded. The section on synthetic fibers has been greatly enlarged to embrace all of the recent

developments in this field. Among the new materials covered are silicones, polectron, polyethylene, furane resins, and resorcin-formaldehyde resins. All of the latest information on synthetic rubbers and rubber-like plastics is to be found in the book.

Of general interest is what the publisher terms "a full-color review of the civilian plastics of the past together with their counterparts of the future as rendered by a group of well-known industrial designers." The photographs and drawings in this introductory section are very good to look at.

The editors have made the material easy to find. In the front of the book is a table of contents of all the articles. The Appendix comprises a subject index, a selected bibliography, a glossary of plastics terms, and an index of advertisers. The trade edition as well as the de luxe edition is tabbed on the title page of each section.

American Standards. Booklet published by the American Standards Association, June, 1945. 24 pages.

A new list of "American Standards" and "War Standards" has just been published by the American Standards Association.

There are approximately 800 standards listed in the booklet, which represent 26 years' cumulative work done by many trade, technical, and governmental groups in conjunction with the Association.

The standards are indexed alphabetically, as well as by engineering fields. There is also a separate list of "war standards" projects undertaken at the request of Army, Navy, or industrial groups. To date 117 such projects have been completed and there are more under way. These war standards have been produced in the fields of safety work, machine tools, quality control, photography, radio, and many others. All have been designed to relieve time, material, and manpower shortages.

Members of Textile Research Institute may obtain this booklet free by writing to the American Standards Association, 70 East 45th Street, New York 17, New York.

Delays in Printing Journal

WARTIME conditions have imposed a burden upon our printer that has made it necessary to continue mailing TEXTILE RESEARCH JOURNAL in the month following the printed date of issue. Copy is being given to the printer in advance of the time normally required and every effort is being made by him and by the JOURNAL staff to obtain an earlier mailing. It is hoped that improvement can soon be made. In the meantime we must request the indulgence of our readers.

ABSTRACTS

SERVICES AVAILABLE

Reprints of the original articles abstracted in TEXTILE RESEARCH JOURNAL *are often available from the publishers. Otherwise, it may be possible to secure copies of the periodicals. A list of periodicals, the abbreviations used in references to articles, and the addresses of publishers of English language publications was given on page 22 of the January, 1945, issue. Orders should be sent direct to the publishers.*

Photostat negatives of articles abstracted will be furnished to members of the Institute at a cost of 15 cents per page for pages not exceeding 7 inches in width and 25 cents per page for larger sizes up to 11½ x 14 inches. Postage will be added.

Microfilm copies and paper enlargements of microfilm may be obtained from: Microfilms Inc., 313 N. First St., Ann Arbor, Mich.; New York Public Library, New York, N. Y.; Yale University Library, New Haven, Conn.; Harvard University Library, Cambridge, Mass.; and Library of Congress, Washington, D. C. Translations may also be obtained from the above sources.

ANALYSIS: TESTING LABORATORY METHODS

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Air Permeability Test

The air permeability of mosquito netting. J. Lomax. *J. Text. Inst.* **36**, T60–6 (Mar. 1945).

The pendulum test appears suitable as an alternative method for ranking as regards air permeability of mosquito or any other netting with an air resistance too low for measurement by the normal method. Assessment can be made by keeping a frame containing a standard specimen of fabric or wire mesh and measuring the number of oscillations given by a sample compared with the standard, the results being given as a ratio of conductivity. This comparative method would eliminate corrections for atmospheric conditions. Author

Color Measurements

Spectrophotometer permits accurate color measurements. Harrison Johnston. *Textile World* **95**, 127–31, 182, 184 (May, 1945).

A description of the theory, use, and application of the spectrophotometer developed by General Electric by which measurements can be made of the color of reflecting materials such as textiles, paints, and paper, or of transmitting materials such as glass, filters, and solutions. The instrument consists of an incandescent light source which radiates light of all wavelengths in the visible spectrum, a double prism monochromator which disperses this light into a spectrum and selects monochromatic light from it, a flicker system for shining it alternately on a sample and a standard, a photo-tube and associated amplifier circuits, and a recorder. Samples are about 3 × 5 cm. A schematic diagram and pictures are shown. Operation is largely automatic and requires relatively little skill. Results can be relative to the international standard of color or a measure of color difference between two samples.

H. J. Burnham

Nylon Solutions

The fluidity of nylon in *m*-cresol—Part 2. J. Boulton and D. L. C. Jackson. *J. Soc. Dyers and Colourists* **61**, 40–47 (Feb. 1945).

A comparison is made between *m*-cresol and formic acid with regard to their suitability as solvents for viscosity measurements on nylon solutions. They are compared for flow properties, sensitivity, stability, and convenience in use; *m*-cresol is preferred. Many results for a large number of yarns have been obtained for sulfuric acid and photochemical degradation. In each case the relationship between loss in strength and rise in fluidity is independent of the origin of the nylon. In the case of photochemical degradation there is a smaller rise in fluidity for a given loss in strength than is the case for acid degradation. Measurements of fluidity of solutions of low concentration of nylon in *m*-cresol are described, and it is shown that intrinsic viscosity is dependent upon concentrations over a wide range of dilutions. Data are given from which the fluidity, as defined for an 8 g. per 100 cc. solution of nylon in *m*-cresol, can be deduced from viscosity measurements made in more dilute solutions for yarns degraded by acid attack. Authors

Spectrometry

Analytical applications of emission spectrometry. J. Raynor Churchill. *Ind. Eng. Chem. Anal. Ed.* **17**, 66–74 (Feb. 1945).

The status of emission spectrometry as an analytical technique in the general analytical laboratory is discussed with particular attention to non-routine applications. A number of techniques, involving qualitative and semi-quantitative tests on a wide variety of materials, are described. Specific examples, drawn from the files of Aluminum Research Laboratories, are given to illustrate the usefulness of the spectrograph in general qualitative analysis in the identification of alloys, in seeking explanations for differences in physical and chemical properties, in the analysis of coatings and platings, in corrosion in-

vestigations, and in a variety of other special applications. The limitations, as well as the advantages, of spectrographic methods in qualitative and quantitative analysis are pointed out. Author

Light absorption spectrometry. M. G. Mellon. *Ind. Eng. Chem. Anal. Ed.* **17**, 81–8 (Feb. 1945).

The analytical applications of light absorption spectrometry involve determination of the absorptive capacity of materials for radiant energy in the wave-length range of 400 to 750 mμ. These are the wave-lengths which produce the sensation of light in the human eye. Since selective absorption results in color, when the unabsorbed radiant energy reaches the eye, this kind of method may be considered as a type of colorimetry. The uses of such absorptive measurements may be grouped into two general categories. Qualitative uses depend upon the kind of absorption—that is, the nature and contour of the transmittance—wave-length curve. In colorimetry this involves the hue of the system. Quantitative uses depend upon the intensity of absorption—that is, the height of the characteristic portion of the curve. In colorimetry this involves luminancy and purity, which in turn depend upon the amount of the absorbing constituent present.

Author

Mass spectrometry. H. W. Washburn, H. F. Wiley, S. M. Rock, and C. E. Berry. *Ind. Eng. Chem. Anal. Ed.* **17**, 74–81 (Feb. 1945).

The observed experimental correlation between mass spectra and structure of hydrocarbon molecules is illustrated by the spectra of the octanes. The large variations of spectra with minor variations in arrangement of atoms in a molecule are responsible for the applicability of the mass spectrometer to analysis of isomeric paraffin mixtures containing as many as 10 components. The analysis of a mixture from its mass spectrum can be obtained from the solution of linear simultaneous equations. However, in samples encountered in the C_1 through C_5 range of hydrocarbons, many components or groups of components can be determined from mass spectrum peaks which receive no contribution from other components in the mixture. This is especially true when the peaks referred to are corrected for the presence of heavy isotope. The resulting simplifications in computing the analyses are illustrated by specific examples. Some types of mixtures which are advantageously analyzed by the mass spectrometer are discussed. A short description of the operation of the instrument is included.

Author

Fabric Testing

Practical details in testing cloths for tensile strength. Staff of the Testing Department, Shirley Institute. *J. Text. Inst.* **36**, S1–14 (Feb. 1945).

Woven fabrics are commonly examined for structural particulars such as weight and threads per inch and for freedom from the more obvious manufacturing defects. Cloth specifications also frequently require a standard of performance in particular tests, the most common of which is undoubtedly the tensile strength. The popularity of this test is understandable and reasonably well founded, for not only is it readily carried out with the aid of a relatively robust machine, but it gives some check of several possible features of the cloth. The replacement of one variety or mixing of cotton by another, the existence of some degree of chemical, biological, or mechanical tendering, the replacement of fiber by filling irregularities or changes in construction not evident by simple inspection can all produce changes in tensile strength that are revealed by tests on specimens. It is therefore important that the results of tensile tests on a cloth shall be as reproducible as possible not only on one machine but also between machines. It is known that there are real differences between the tensile strength results obtained with different machines and that the most important single factor responsible for these differences is the rate of loading of the specimen. It is customary, therefore, to specify the type of machine that is to be used and also the rate of loading or rate of traverse depending upon whether a machine having a constant rate of loading or constant rate of traverse is to be used. The present article is not concerned with these aspects of tensile strength testing but with the variety of practical details which arise when tests are to be made on a given machine with a stated rate of loading or traverse. There are some rules which must obviously be observed; the machine must be clean, lubricated, free from avoidable friction and looseness of parts, and must give a reading as nearly correct as possible. There are decisions to be made about method when the choice of alternatives is not self-evident; for example, how specimens are to be prepared from "bowed" fabric, and whether fringes should be left on specimens. There are also rules of operation which must be followed and which are not so obvious; for example, the necessity of mounting a specimen in the machine truly centrally in the grips. The practice of such rules distinguishes the skilled machine operator from the unskilled. Like many machines the tensile strength testing machine does not automatically give the same response to skilled and unskilled users. This account deals with practical points, from the reception of a sample to the breaking of the specimen on the machine, and is divided into two parts—the preparation of specimens and the testing of them on the machine. The discussion of the second part is based upon the use of a horizontal Goodbrand Type C cloth-testing machine. Many of the factors considered are peculiar to horizontal machines of this type but some are of more general application.

Author

Testing Tear Resistance

Initial tear tester. A. C. Poulter. *Patra J.* **8**, 14–22 (1944) (through *Chem. Abstr.* **39**, 1944, 1050[9]).

Details are given for modifying the Schopper tensile tester by the addi-

tion of a clamping unit so that it can be used for determining the initial tear of paper, cloth, etc. The results appear to be independent of the rate of tearing but are influenced by the distance between the clamps and the depth of material in the clamp. The test is empirical and there is no constant ratio between the initial to Marx-Elmendorf tearing resistance for various papers and films.

CHEMICAL AND PHYSICAL RESEARCH

★

Cellulose Acetate Fractions

Cellulose acetate fractions. Intrinsic viscosity and osmotic molecular weight. Arnold M. Sookne and Milton Harris. *Ind. Eng. Chem.* **37**, 475–7 (May 1945).

The intrinsic viscosities and osmotically estimated number-average molecular weights of a series of cellulose acetate fractions have been measured. It was found that, within the range of chain lengths investigated (number-average molecular weight up to 130,000), the number-average molecular weights are proportional to the intrinsic viscosities in acetone solutions, in agreement with Staudinger's rule and the results of Kraemer. An estimate is provided of the relative homogeneity with respect to molecular size of the fractions and the starting material from which they were prepared. 9 references. Authors

Cellulose Esters

Effect of environment on permanence of acetate and nitrate sheets. T. S. Lawton, Jr., and H. K. Nason. *Modern Plastics* **22**, 145–50, 176, 178 (Jan. 1945); *cf. B.I.P.C.* **15**, 86–7 (through *Bull. Inst. Paper Chem.* **15**, 234).

The effect has been studied of environmental conditions, such as weathering, ultraviolet light exposure, moisture exposure, heat exposure, etc., on the permanence of cellulose acetate and nitrate plastic sheets of typical, representative production materials. Wherever possible, A.S.T.M. standard test methods were used; the outdoor weathering panels were exposed in Miami, Fla., and in Springfield, Mass. Cellulose acetate was found moderately resistant to outdoor ageing, whereas cellulose nitrate tends to degrade and lose its properties rather rapidly; the former is more sensitive to moisture, whereas the effect of temperature is about the same for both. Tensile strength, elongation, and yield stress for both cellulose acetate and cellulose nitrate decrease with increasing outdoor exposure time, until a stage is reached where the mechanical properties can no longer be measured. Approximately three times as long is required to degrade the acetate as is required for the nitrate. The degradation of the latter seems to start soon after exposure, whereas the acetate exhibits a more gradual change. The impact strength of both materials decreases with increasing exposure, whereas light transmission, haze, and shrinkage increase. Exposure is more severe in Florida than in Massachusetts. To obtain the same effect caused by one year's exposure in Florida, approximately 15 months' exposure is required in Massachusetts; the ratio appears to be the same for both plastics. Degradation caused by outdoor exposure can be measured by viscosity determinations. Most of the degradation appears on the surface, gradually penetrating deeper, as the period of exposure increases. The cellulose nitrate shows a much greater decrease in molecular weight than does the acetate for the same exposure period. After 12 months' exposure in Florida, the acetate sheet had lost about 20% of its plasticizer content, whereas the nitrate sheet lost about 33% after six months. On immersion in water, the nitrate was more resistant to moisture than the acetate; on continued immersion, both materials appear to reach equilibrium. 21 references, numerous graphs, and tabulated data.

Cellulose Products

Cellulose and its degradation products as obtained and employed industrially. Valerio Costanzi. *Ion* **4**, 464–70, 531–9 (1944) (through *Chem. Abstr.* **39**, 1981[5], May 10, 1945).

A review.

Mechanical Properties of Cellulose Acetate

Polymolecularity and mechanical properties of cellulose acetate. Arnold M. Sookne and Milton Harris. *J. Research, Natl. Bur. Standards* **34**, 467–76 (May, 1945).

The tensile strengths, ultimate elongations, and folding endurances of films prepared from a series of cellulose acetate fractions and blends were studied. When the mechanical properties are plotted against the intrinsic viscosities (or relative weight-average degrees of polymerization), the results for the fractions and different blends fall on separate curves. In contrast, when the mechanical properties are plotted against the number-average degrees of polymerization, the results for the fractions and all of the blends fall approximately on a single curve for each property. The results are shown to be qualitatively consistent with the hypothesis that the mechanical properties of blends are the weight-averages of the properties of their components. The results emphasize the importance of the determinations of the number-average degree of polymerization in studying commercial polymolecular materials.

BLEACHING: DYEING FINISHING

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Dyeing Nylon

The coloration of nylon. VI. Dyeing with direct cotton dyes. Anon. *Silk J. Rayon World* **20**, 36, 38 (July, 1944).

A discussion of the dyeing of nylon with direct cotton dyes. These have only slight affinity for nylon when applied by the simple methods used for cotton or viscose but they may be satisfactorily used by the addition of a suitable assistant to the dye bath or by pre-treatment

of the nylon. The use of an acid dye bath, especially a 2% or 3% acetic acid solution, has proved to be advantageous. The advantages and drawbacks to pre-steaming of the nylon are discussed. Lists of direct dyes having good affinity for nylon and those having no affinity are given. Also listed are printing recipes which have been found useful. In general, direct dyes having only one or two sulfonic acid groups prove more satisfactory than those with a higher number. E. G. M.

Dyeing and Printing

Some comparisons in dyeing and printing methods. J. W. Reidy. *J. Soc. Dyers and Colourists* **61**, 37–8 (Feb. 1945).

The usefulness of the various classes of dyes to the dyer and printer are compared; essentials of their application are described. Mordant dyes (excluding acid chrome dyes) are of slight interest to the dyer but important to the printer; however, they may find use in dyeing in the future if steam fixation is employed. Direct dyes are of general importance in both dyeing and printing, and, in the latter, especially for white or colored discharge styles. With the exception of the Indo Carbon CL brand, sulfur dyes are not used by the printer. The dyeing properties of the vat dyes give very little indication of their printing properties. The printer uses carbonates as alkali, whereas the dyer uses caustic. Indigoid-type vat colors are used to a much greater extent in printing than in dyeing. Pigments are used for both purposes, the mechanical fixation in printing having the advantage of visual control not possible in *in situ* formation as in dyeing. When it is desired to print heavy shades on acetate rayon, the printer must resort to saponification and treat the cloth as cellulose, while the dyer can obtain heavy shades with acetate dyes in the usual manner. K. S. Campbell

Printing Acid Dyes on Cellulose

The mechanism of the printing of acid dyes on cellulosic materials. W. Meitner. *J. Soc. Dyers and Colourists* **61**, 33–6 (Feb. 1945).

A few acid dyes without affinity for viscose rayon under normal dyeing conditions have good fastness properties when printed on this material from a paste containing urea and steamed. It is claimed that the fixation is not due to the urea. Measurements of dye particle size (in solution) were made by diffusion methods and the size of those which are known to be suitable for viscose printing was found to fall within a certain range. These must be dyes which in cold solution contain particles too big to enter the fiber. Fixation cannot be explained by simple swelling of the fiber pores by steam and occlusion of the dye particles on contraction, since immersing the viscose in hot dye solution and then allowing the fiber to cool results in no permanent retention of dye. It is suggested that the fixation of the acid color on viscose in the presence of moist steam or urea and steam is the result of the reaggregation within the viscose fiber of dye particles which have split during steaming into particles small enough to enter the material; i.e., a particle size equilibrium is set up within the fiber which corresponds to the equilibrium existing in the paste under conditions of steaming. Cuprammonium rayon apparently has larger pores than viscose and for this reason requires dyes with a larger particle size than required by viscose for fixation to take place. K. S. Campbell

Calico Printing

The evolution of calico printing. J. S. Heaton. *J. Soc. Dyers and Colourists* **61**, 31–3 (Feb. 1945).

The major technical developments responsible for the progress in calico printing from the end of the 18th century (when the time required by ordinary cloth finishing processes was at least 8 months) to the present day are discussed. These include steam fixation, the growth of the synthetic dye industry, hydrosulfite discharge styles, the acid ager, and continued improvement in naphtol-type colors for printing. It is emphasized that the trend is now toward smaller and more flexible print works units. K. S. Campbell

Textile Printing

Block printing; old and new. E. S. Beton. *J. Soc. Dyers and Colourists* **61**, 29–31 (Feb. 1945).

The development of block printing from about 1840 to the present time is traced by a brief description of each of a series of 34 exhibits.
K. S. Campbell

Wetting Agents

Rayon dyeing: factors in leveling—VI. Wetting-out agents that give even dyeing and protection to viscose. Anon. *Silk and Rayon* **19**, 105–6 (Jan. 1945).

A review of the use of wetting agents in sizing, scouring, mercerizing, dyeing, and finishing. E. G. M.

Diastase Preparation in Yarn Sizing

Modern diastase utilization as a solubilizing enzyme in the preparation of yarns. Juan B. Puig. *Ion* **4**, 471–80 (1944) (through *Chem. Abstr.* **39**, 1763[4], Apr. 20, 1945).

A discussion of the use of pancreatic and vegetable diastases in the sizing and finishing of textiles with examples of their use, including equipment and size composition. Partial hydrolysis of the starch results in better and deeper fixing of the sizing materials to the textile and improves uniformity, elasticity, smoothness, softness, polish, strength, and life of the textiles.

Protection Against Fungi

Protection of vegetable fibers from attack by fungi. Paulo da Rocha Azevado and Francisco J. Maffei. *Anais assoc. quím. Brasil* **3**, 120–7 (1944) (through *Chem. Abstr.* **39**, 1993[6], May 10, 1945).

In laboratory tests the most effective treatment of cotton canvas consisted in immersing the canvas in a 10% solution of $CuSO_4$, wringing out the excess and immersing in a 10% NaOH solution; after thorough washing the canvas is heated 1 hour

at 1 atmosphere pressure. For an accelerated rotting test strips are cut and interlayered with strips of rotten canvas; the treated and untreated strips thus inoculated are stored under conditions of tropical warmth in a moist atmosphere for 60 days. In this test the treated strips lost nothing in breaking strength whereas the untreated were practically disintegrated.

Resins on Textiles

Newer resinous materials and their effects on various fibers and fabrics. D. H. Powers. *Am. Dyestuff Reptr.* **34**, P77–9 (Feb. 12, 1945).

The developments of the past few years with regard to the coating and impregnation of textiles with resinous materials are reviewed. Much work has been devoted to keeping production up in spite of shortages, with definite decrease in research. The properties of resins used in treating raincoats, ponchos, tentage, wool for shrinkage control, cotton and rayon for increased launderability and stability without the danger of chlorine retention, are discussed. Resin dispersions in water and in organic non-solvent and polymerized silica dispersions are described. K. S. Campbell

FIBERS: YARNS: FABRICS MECHANICAL PROCESSES

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Alginate Rayons

Some properties of alginate rayons. N. H. Chamberlain, A. Johnson, and J. B. Speakman. *J. Soc. Dyers and Colourists* **61**, 13–20 (Jan. 1945).

The alginate rayons possess far greater hygroscopicity (e.g., approximately 23% at 50% R.H. for chromium alginate) than other textile fibers and show marked adsorption-desorption hysteresis. Their regain increases rapidly with increasing metal content. There is an optimum metal content for each alginate with regard to tenacity. The tensile strengths and extensibilities are greatly affected by the relative humidity. Beryllium alginate, for example, has a tenacity of 2.8 g. per denier at 0 R.H. and 1.08 at 100% R.H. Alginic acid rayon loses practically all of its strength at saturation, whereas the beryllium derivative (because of its high coordinating power and consequent ability to give non-ionized cross-linkages) retains 70% of its strength in water. The latter product, together with the chromium alginate, suffers from such low extensibility that it cannot be woven or knitted successfully. The density of all the metallic alginates exceeds 1.7 and it is clear that lightweight full-handling fabric will be difficult to produce. They do have the advantage of excellent draping qualities and the high metal content renders them non-inflammable. Calcium alginate is soluble in a solution of 0.2% soap and 0.2% soda ash, but chromium and beryllium alginates are very slightly affected in this solution after treatment for 30 min. at 40° C. Because calcium alginate has elastic properties which will allow satisfactory knitting and weaving and since its storage properties are good, it is indicated that seaweed rayons will be first produced and processed in this form and will then be made alkali-resistant if desired by conversion to the chromium or beryllium alginate by a finishing process. K. S. Campbell

Felting Properties of Animal Hair

The felting and fulling properties of animal hairs. W. Grassmann and O. Engel. *Collegium* **1943**, 113–29 (1943); *Chem. Zengr.* **I**, 329–30 (1944) (through *Chem. Abstr.* **39**, 1764⁴, Apr. 20, 1945).

Calf hairs were subjected first to an alkaline treatment, particularly $Ca(OH)_2$ solution with addition of Na_2S. Untreated hairs are readily felted, but could not be fulled. The felting property is nearly always decreased somewhat by the alkaline treatment. The influence on the fulling property varies greatly with the nature of the treatment, the chemicals used, and the length of the treatment. No definite relationship could be established between the staple diagrams and fulling power. Slightly damaged or undamaged cattle hair cannot be fulled; in general the fulling property is proportional to the alkali damage.

Flax Processing

New linen process has kinks—but they're being worked out. Ray Freedman. *Textile Bulletin* **68**, 31 (Apr. 15, 1945).

R. E. Montonna and Lloyd Reyerson of the University of Minnesota are said to have developed a chemical process for the making of high-grade linen from flax at costs far below the price paid for imported linen produced by old-fashioned methods. No details of the process are given, it being stated that it is not yet patented. Some kinks in the process will be overcome, it is hoped, in a $5,000 pilot plant which is being planned now. It is believed that 1 ton of fiber can be produced from 10 tons of straw. H. J. Burnham

Textile Fiber from Casein

Textile fiber from casein. Factors affecting the tensile strength. R. F. Peterson, T. P. Caldwell, N. J. Hipp, R. Hellbach, and R. W. Jackson. *Ind. Eng. Chem.* **37**, 492–6 (May, 1945).

Studies on the preparation of fibers from acid-precipitated casein with a laboratory spinning machine are reported. Attention was directed to the major operations of fiber production—namely, dissolving the casein, spinning, stretching, and hardening. A spinning solution containing 20% protein and having a pH of 9.2 was employed in most of the experiments. All fibers were given a final hardening treatment with formaldehyde. Stretching the tow issuing from the spinneret, either in the precipitating bath or between godet wheels in air, gave a tensile strength of about 0.7 g. per denier. Under these conditions of stretching, the additon of aluminum sulfate to the precipitating bath containing sulfuric acid and sodium sulfate did not affect the strength

of the fiber. However, such incorporation of aluminum sulfate had a marked effect in a subsequent operation involving simultaneous stretching and partial hardening with formaldehyde. When the latter process was operated at 85° C, a dry strength of 1 g. per denier and a wet strength of 0.5 g. per denier were obtained. Comparative measurements of tensile strength of artificial protein fibers which will be exposed to moisture are best made after the fibers have been swollen in water and dried. 30 references. Author

Cotton Spinning

The past, present, and future of cotton spinning machinery. G. H. A. Sington. *J. Text. Inst.* **36**, P13–23 (Feb. 1945).

An address. A. R. Martin

Irregularities in Yarns

A new method of measuring the irregularity of yarns, with some observations on the origin of irregularities in worsted slivers and yarns. J. G. Martindale. *J. Text. Inst.* **36**, T35–47 (Mar. 1945).

A new method of determining the irregularity of the weights of 1-in. lengths of yarn is described. Its advantages are that it enables weighings of a large number (1,600) of these lengths to be made accurately and comparatively quickly on simple apparatus. The origin of irregularities in slivers and yarns is discussed, reference being made to the work of others who suggest that drafting waves may be responsible for these irregularities. It is suggested that such waves are only partly responsible for the irregularity of worsted yarns. An examination of the worsted processes is made, to show that one can legitimately infer that even the most perfect drafting equipment with full control of short fibers would not give a uniform sliver or yarn, but only one in which the fibers were arranged at random. Such a random arrangement would produce an irregular product. The degree of irregularity of thickness arising from a random fiber arrangement can be calculated and a formula is developed from which the calculation can be made. This shows that the irregularity arising from this kind of fiber arrangement is dependent only on the mean number of fibers per cross section and the variability of the fiber thickness, and is independent of any other fiber properties, including length or variability of length. Experimental results are given which show that, without exception, in worsted slivers and yarns the measured irregularity is always greater than that which should arise solely from a random fiber arrangement. One of the interesting features of the results, however, is the large part of the irregularity of fine rovings and yarns which must be ascribed to the effect of a random arrangement of fibers, rather than to any such cause as uncontrolled short fiber movement during drafting—i.e., the drafting wave. Author

Yarn Strengths

Yarn strength of Egyptian cotton mixings. Frank Dunkerley. *J. Text. Inst.* **36**, T57–9 (Mar. 1945).

The statement made in a previous paper, that the yarn strength of a mixing of Egyptian cottons is nearly equal to the weighted mean of the yarn strengths of the components, is now amended to read: "The yarn strength of a mixing of Egyptian cottons is equal to the weighted mean of the yarn strength of the components." No "strength bonus" of the mixings was found. As several years of extra experience in the spinning and testing technique for small samples have been gained since the last series of experiments was reported, and as the precautions taken to insure identical treatment of all samples at each stage were even more stringent than in the previous experiments, it is felt that the results obtained are representative of the true state of affairs. The reason for the previously found "strength bonus" of the mixings, which has entirely disappeared, is still a mystery. It might have been the result of some undetected error introduced into the roller settings at the speed or ring frames. However the "strength bonus" came about, it can now be said with confidence that mixings of two Egyptian cottons will produce yarn with a strength very closely equal to the weighted mean strength of the components. In point of fact, only one mixing deviated by as much as 2 percent from its expected strength, and this deviation included all possible sources of error. The yarn strengths of the mixings were, on balance, about 3 lea-product units lower than the expected strengths; this deviation is less than 0.2 percent and is entirely negligible. Author

Imitation Furs

Furs from vats. Anon. *Plastics* (Chicago) **2**, 36–7, 39–40, 114 (Apr. 1945).

A new process known as the Calva process permits the simulation of expensive furs by the special treatment of sheepskin and similar materials. These retain their beauty and luster after repeated wear, dry-cleaning, and exposure to rain. In the manufacturing process, shorn sheepskins are treated to imitate short-haired furs, and the unsheared skins to imitate long-haired ones. Two methods of manufacture are used: (1) The tanned shearling is placed in a solution of cresol, alcohol, benzol, and water maintained at 38° C for 120 min., during which time an acid is introduced for activating the keratin. It is then submerged in formaldehyde at 45° C for 20 min. (2) The fur side of the pelt is brushed by hand with the same substances. In either case the skin is then washed, dried, heated, clipped for uniform length, polished, and dyed. The process is explained as follows: the acid breaks the salt-linkages between neighboring polypeptid chains and also causes some hydrolysis. The free amino and imino groups then react with formaldehyde to form methylene links between the chains. At the same time, a cresol-formaldehyde resin is formed within the fiber. The overall result is that wool fibers which were kinky, permeable to water, and prone to mat are straightened and

rendered resistant to water, chemicals, and abrasive action. The process is said to make possible the production from shorn wool of a felt that is indistinguishable from fur felt, and to permit the conversion of bristle, cordage, carpeting, and clothing into materials possessing new appearance and properties.

E. G. Martin

Textile Drying Machines

Textile drying machines. Anon. *Silk J. Rayon World* **21**, 34–7 (Jan. 1945).

A description of the different types of tenter frames including the fixed hand-frame with pin-rails, clip-tenters, and the modern improvements on these two fundamental types. When heated air was introduced to dry the fabric, an insulating layer of static air often resulted. This has been overcome by introducing the hot air through thin streams in nozzles of a truncated Venturi type which cause sufficient turbulence to break down the boundary layer. A description is given of the brattice drier and of a special tubular drier for knit goods. 3 photographs and 10 diagrams are included. E. G. Martin

MISCELLANEOUS

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Paper Laminates

The use of various papers in paper laminates. Robert W. Barber. *Paper Trade J.* **120**, 46–9 (May 10, 1945).

Cellulose fibers are used in many forms in the manufacture of plastics; the end use being the factor determining the qualities required. They are incorporated to reinforce and strengthen the plastic material, which is laminated and usually stronger than the comparable molded product. A summary is given of the materials used in the manufacture of laminates. The construction and the characteristics of the fiber of the paper used as the base are most important to the strength properties of the plastic. Formation, furnish, tensile strength, density, and absorbency are of particular interest. The uses of paper laminates are many and varied and can be expected to increase. Typical uses considered herein pertain to their application in refrigerators, aircraft flooring, and die construction. Author

Macromolecular Chemistry

Macromolecular chemistry. S. H. Pinner. *Chemistry and Industry* **No. 18**, 138–40 (May 5, 1945).

A brief review. A. R. Martin

Plastics

The x-ray examination of plastics. W. T. Astbury. *Chemistry and Industry* **No. 15**, 114–6 (Apr. 14, 1945).

An address. Photographs are given of x-ray diffraction patterns of 12 plastics. E. G. Martin

Definition of Term *Rayon*

Rayon—what is it? A. G. Scroggie. *Textile Age* **9**, 42, 44, 46 (Apr. 1945).

Conflicting definitions are given for rayon as used in the U. S. and in England. In America, the term "rayon" is applied only to those fibers from a cellulose base, whereas British usage applies it to "all fibers for textile use which are not of natural occurrence." It is argued that a new term should be promoted to represent all man-made fibers and that the term "rayon" should be restricted to cellulose-base fibers. The paper has been transmitted to England through the A.S.T.M., the American Standards Association, and the British Standards Institution. H. J. Burnham

Saran Monofilament

New Saran monofilament for braided wire and cable. Anon. *Plastics and Resins* **4**, 9–11 (Feb. 1945).

Results are given for tests made on Saran braided cable assemblies and Saran braid over 0.030" vinyl-covered hook-up wire. These show only slight shrinkage over a wide range of temperatures, high resistance to corrosive chemicals, high resistance to abrasion and moisture absorption, and are mildew proof.

E. G. Martin

Silicones

Silicones. R. W. Kolderman. *Can. Chem. and Proc. Ind.* **29**, 147–52 (Mar. 1945).

Silicones are a new class of semi-inorganic condensation high polymers. They are derived from silicon tetrachloride, magnesium, and organic chlorides by means of the Grignard reaction, followed by hydrolysis and condensation. Their heat resistance, general inertness, and good dielectric properties are due, in part, to the fact that they are built upon interlacing structures of silicon and oxygen atoms. Silicone products include liquids, dielectrics, lubricants, greases, resins, and varnishes. Properties, characteristics, and uses of each of these are discussed. A bibliography of silicone literature, including 16 references, is given. E. G. Martin

Color of Soils

Color of soils. Dorothy Nickerson, K. L. Kelly, and K. F. Stultz. J. Opt. Soc. Am. **35**, 297–300 (1945).

Color data on soils, foliage, and grasses are presented in scatter diagrams of the Munsell type to show the concentration of color; also spectrophotometric curves of typical samples. D. Nickerson

Preparation of Stearic Acid

Preparation of pure stearic acid. J. M. Philipson, M. J. Heldman, L. L. Lyon, and R. D. Vold. *Can. Chem. and Proc. Ind.* **29**, 120–1 (Feb. 1945).

Previously described methods for the preparation of stearic acid have yielded pure products but in insufficient quantities; lack of detail as to procedure and manipulation has caused excessive loss of time. To remedy these inadequacies the method as outlined by Hilditch in the "Chemical Constitution of Na-

tural Fats" is here used. By this method 200 g. of pure stearic acid may be obtained from 500 g. of technical stearic acid. This method involves the lead salt separation of the saturated from the unsaturated acids, conversion to the methyl esters, fractional distillation of the esters *in vacuo*, hydrolysis of the methyl stearate to stearic acid, and recrystallization from acetone. The setting point is considered to be the most useful constant for comparison of the purity of various stearic acids. E. G. Martin

Synthetic Rubber

Synthetic rubber. B. J. Habgood. *Ann. Rept. Progress Rubber Technol.* **7**, 25–46 (1943) (through *Chem. Abstr.* **39**, 1775[8], Apr. 20, 1945).

A review of important 1942–1943 literature, with 345 references.

Transference of Color

Report of A.A.T.C.C. subcommittee on transference of color. D. P. Knowland, chairman, and W. A. Holst, secretary. *Am. Dyestuff Reptr.* **34**, P166 (Apr. 23, 1945).

This committee recommends the preparation of a chart for rating crocking fastness on a 1–5 scale, the color chart to be composed of a series of Munsell values 9/ through 6/, each value to include a neutral and a low chroma of red, yellow, green, blue, and purple—on the 9/ value level the chroma to be /1; on the 8/, 7/, and 6/ value levels the chroma to be /2. The rating method proposed, as applied to crocking tests carried out on the Crockmeter by the usual technique, is as follows:

	Rating
Practically unstained	5
Equal to 9/1	4
Equal to 8/2	3
Equal to 7/2	2
More heavily stained than 7/2	1

Fractional or decimal values between these figures can be interpolated by the observer. D. N.

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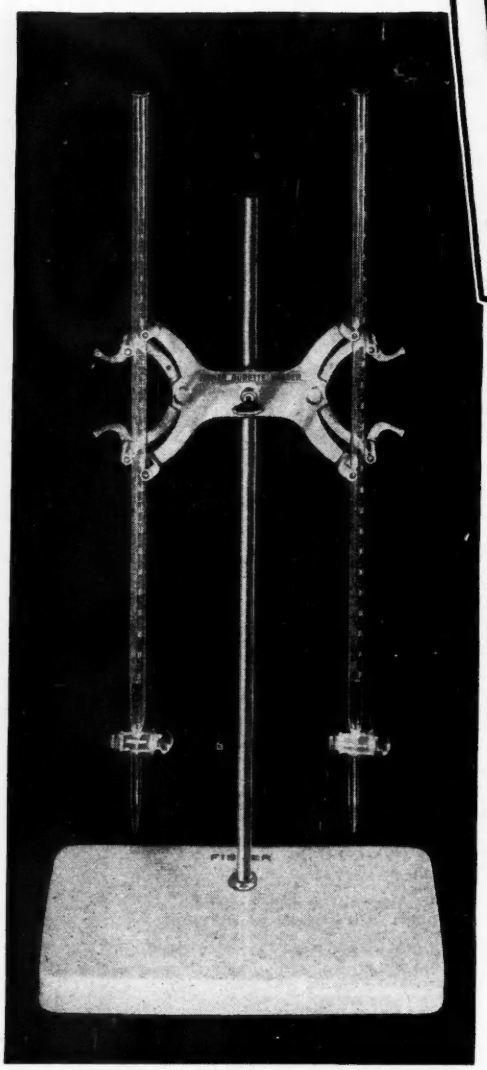

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